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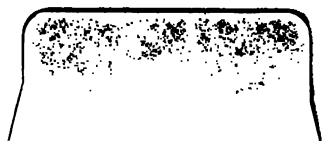
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AN INTRODUCTION

TO THE USE OF THE

MOUTH-BLOW PIPE.



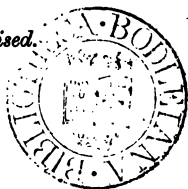
AN INTRODUCTION
TO THE USE OF THE
MOUTH-BLOWPIPE

BY
DR. THEODORE SCHEERER;

TO WHICH IS ADDED
A DESCRIPTION OF THE BLOWPIPE CHARACTERS
OF THE MORE IMPORTANT MINERALS.

BY
HENRY F. BLANFORD, F.G.S.

Third Edition, revised.



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PREFACE TO THE FIRST EDITION.

My object in preparing and publishing this little work is to render available to the English student of Chemistry and Mineralogy a small, cheap, and I trust reliable Manual on the use of the Mouth-Blowpipe, containing so much information as may enable him with this instrument to examine qualitatively any mineral or inorganic compound submitted to him.

The work is rather to be regarded as a compilation than as an original treatise, since the first part, with the exception of a few paragraphs, is almost a literal translation of Professor *Theodore Scheerer's* 'Löthrohrbuch,' and for the material of the second part I am principally indebted to Professor *Plattner's* work on the Blowpipe, and occasionally to the works of *von Kobell* and *Rammelsberg*.

I have, however, throughout the greater part of the present work carefully verified every statement, and where my authorities were deficient, have supplied the necessary details from personal experiment. For the Blowpipe characters of the metallic minerals I am

obliged to rely principally on the authority of Professor *Plattner*, owing to circumstances which, I regret to say, have prevented my completing my proposed series of verification.

I have not deemed it necessary to detail the Blowpipe characters of every known mineral, since such an attempt would, by unduly extending the limits of the book, defeat the object I had proposed to myself in preparing it, and as moreover in Professor *Plattner's* work, a translation of which has been published by Dr. *Muspratt*, such information may be obtained by the more advanced student. I have therefore only noticed those mineral species, which are of comparatively frequent occurrence, or those which, being rare, nevertheless present such well-marked Blowpipe characters as to render them good examples for practice.

Any eulogium on the Blowpipe as an aid to the Chemist and Mineralogist is unnecessary; its advantages will be at once apparent to all who persevere in its practice; and if the following pages should, by supplying to the English student a cheap and concise handbook, tend to extend its use, I shall consider myself amply remunerated for any time and labour I have devoted to their preparation.

H. F. B.

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PART I.

INTRODUCTION.

For many centuries, the workers in metals of various countries have employed the small instrument which forms the subject of the present treatise, in fusing the solder by which the different parts of their work are united. The simplest and most ancient form of blowpipe, and that which is still in general use for such purposes, is a conical brass tube, curved at the smaller end into a right angle and terminating with a small, round and regular orifice. When used, the larger end of the instrument is held in the mouth and a continuous stream of air blown through it, which, passing through the flame of a lamp, is made to impinge upon the solder or other substance submitted to its action, thus imitating upon a small scale the action of a blacksmith's forge.

In this rude form the blowpipe was of no importance in scientific investigation ; the means by which it has gradually attained to its present importance as an aid to the chemist, the mineralogist, the miner and the smelter in enabling them by a short and easy process to ascertain the chemical nature of the various substances submitted to them, will be shown in the following historical sketch.

So far as is recorded, *Antony Swab*, a Swedish councillor of mines who lived towards the commencement of the last century, was the first who experimented upon the application of the blowpipe to the chemical investigation of ores and minerals. After him, the Swedish mineralogist *Cronstedt* used the blowpipe to aid him in distinguishing various minerals, especially with reference to the mineralogical system founded by him in 1758, and *Engeström*, who in 1770 published an English translation of *Cronstedt's* "System of Mineralogy," introduced into his work a description of that mineralogist's mode of using the blowpipe. In 1773 *Engeström's* description was translated into Swedish, and shortly afterwards into many other European languages. However imperfectly the use of the blowpipe was at that period understood, it soon, by its certain and readily obtained results, excited much attention ; but for some time, owing to the large amount of practice required for its successful application, but little progress was made in its manipulation. Its use was much extended by *Bergmann*, who employed the blowpipe for qualitative investigation in all branches of Inorganic Chemistry, and who showed how by the aid of this instrument it is possible to recognise very small traces of mineral substances which could only be discovered with great difficulty by any other process.

Bergmann published the results of his experiments in a work in the Latin language printed at Vienna in the year 1779 and translated by *Hjelm* into Swedish in 1781.

After *Bergmann's* death, which occurred shortly after the publication of his work, *Gahn* made further progress in the path of investigation struck out by that author.

By long continued practice and much perseverance he attained great skill in the use of the blowpipe, but he unfortunately never published any of the rich results of his experience, and these would have been entirely lost had it not been for the ready liberality with which he communicated his art to all who desired to acquaint themselves with it. It was thus that the young *Berzelius*, whom *Gahn* especially distinguished as a disciple of his art, was enabled to avail himself of the experience of the latter, and upon this foundation to build up a loftier structure. In the selection of *Berzelius* as his pupil, *Gahn* evinced the greatest judgment, for it would have been difficult to find any one more fitted to be his successor. Not only did *Berzelius* extend and improve the application of the blowpipe to a high degree, but, at the same time, by his personal instructions and by his writings, he spread abroad the knowledge of this instrument, so that, at the present day, the use of the blowpipe forms an essential part of the knowledge of every chemist. In 1821 *Berzelius* published his excellent work entitled "The Use of the Blowpipe in Chemistry and Mineralogy," a work which has since passed through many editions and has been translated into most of the European languages.

Up to this period the attention of blowpipe investigators had been turned solely to the application of this instrument in qualitative research.

It was *Harkhort* who first entertained the idea of employing the blowpipe to ascertain the quantities as well as the nature of mineral ingredients, and who thereby founded the important art of assaying with the blowpipe. In the year 1827 he published at Freiberg the first part

of his "Probirkunst mit dem Löthrohre," containing the results of his experiments on the assaying of silver with that instrument, and this was the only writing which ever appeared from his hand, for shortly after its publication he left Europe for Mexico, and was thus unable to publish the second part, in which he intended to describe the methods he employed for assaying lead, copper and tin.

Plattner, recognising the importance of continuing and extending the researches of *Harkhorst*, applied himself for many years to this object, and, by his perseverance and skill, he has succeeded in bringing the art of assaying with the blowpipe to a degree of perfection which would formerly have been deemed unattainable, and obtains results which in some cases surpass, both in accuracy and rapidity, those obtainable by the delicate processes of chemical analysis. *Plattner* has published the results of his experiments on both qualitative and quantitative blowpipe analysis in his excellent work "Die Probirkunst mit dem Löthrohre," of which the first edition appeared in 1835, the second in 1847, and a third and much extended edition in 1853.

Under *Berzelius* and *Plattner* the use of the blowpipe in qualitative and quantitative analysis has become so comprehensive in its details that considerable time and practice are requisite before the student can render himself master of the art ; and this is especially the case with regard to quantitative assaying, which is in consequence seldom practised by chemists, but only by some few professional assayers in various parts of Germany. In the following treatise it is intended to present a brief

but comprehensive description of the most important processes of qualitative research with the blowpipe ; and it is hoped that, by the aid of this little work, students in Mineralogy and Metallurgy may be enabled to regard the blowpipe as a useful, faithful friend.

I.
THE BLOWPIPE FLAME AND APPARATUS FOR
QUALITATIVE RESEARCHES WITH THE
BLOWPIPE.

It has already been mentioned that the blowpipe flame is produced by forcing a small continuous stream of air by means of the blowpipe through the flame of a candle or lamp, and in a more or less inclined direction. The best flame for the purposes of the blowpipe operator is given by an oil-lamp with a broad and moderately thick rectangular wick, the lamp being supported on a small brass pillar in a manner hereafter described. The principal points to be attended to in the production of a good flame are 1. that the stream of air be constant and regular, and 2. that it be properly directed and applied. The first of these points will be treated of more at length under the description of the blowpipe ; but with regard to the second a few words in this place will be necessary. According to the mode in which the flame is produced, it is in the power of the operator to direct either an oxidising or

reducing flame upon the body he subjects to its action, and indeed these two flames form the principal agents employed in blowpipe investigations. Hence it is of the utmost importance to the student that at the outset, he render himself thoroughly master of his flame, so as to be enabled to vary its chemical action at will, and to produce a regular and well sustained blast. This point attained, he has conquered the principal difficulty which presents itself to him in his whole course of blowpipe studies.

In order to obtain a reducing flame, the nozzle (*b*, Fig. 1) of the blowpipe (the stem of which is for convenience here omitted) is held in an inclined direction parallel to

Fig. 1.



Fig. 2.



the surface of the wick and just touching the exterior surface of the flame. A bright yellow flame will be thus produced of the form shown in the figure.

An oxidising flame is obtained by keeping the nozzle of the blowpipe at the same inclination as in the former case, and introducing it into the flame to about one third the breadth of the wick (*b*, Fig. 2), at such a distance only from the surface of the latter, as to obtain a clear unbroken flame.

It is desirable to blow a somewhat stronger blast than is required for the reducing flame. The flame so pro-

duced is of a pale blue color and almost invisible by daylight.*

The brilliant yellow color of the reducing flame is due to extremely minute particles of carbon, which pass from the wick unconsumed but at a white heat, and which, coming in contact with the substance submitted to the flame, exercise a reducing action upon it. In the oxidising flame, on the other hand, all the carbon of the gases in the interior of the flame is converted into carbonic acid and carbonic oxide; and the blue color of the flame-cone is due to the further combustion of the latter gas.

It is easy to understand the principles on which the two different flames are produced according as the operator manipulates in one or other of the modes above described. In the case of the reducing flame, the entire flame of the lamp is forced aside by a weak current of air impinging on its outer surface, and it is therefore unchanged except in direction; whereas in the oxidising flame a strong blast of air is poured into the interior of the flame, which, becoming thoroughly intermingled with the various inflammable gases evolved from the wick, produces an almost perfect combustion. If then a small fragment of an oxidisable substance be held just beyond the point of this flame it becomes intensely heated, and being exposed freely to the action of the surrounding atmosphere,

* In order to exercise himself in the manipulation of the blowpipe flame, the student will do well to practise the reactions afforded by the oxides of copper and manganese or molybdic acid in the borax bead as described on page 48.

it is rapidly oxidised. If the blast from the blowpipe be extremely strong, a portion of air passes unconsumed through the centre of the flame and increases the oxidising action of the latter.

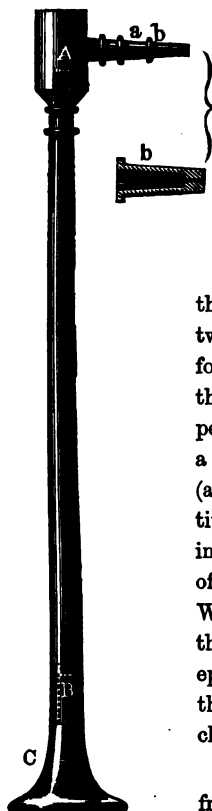
It is not however as an oxidising agent alone that this flame is used : on account of its great heating power it is also employed in order to ascertain the fusibility of various substances, and for effecting fusions in all cases in which a reducing action is not essential.

When any substance is submitted to the action of the reducing flame it should be so held as to be entirely surrounded by the yellow flame and protected from the oxidising action of the surrounding atmosphere ; but this condition being fulfilled, it should be held as near as possible to the point of the flame, in order to gain the greatest amount of heat, and prevent any deposition of soot which would shield the substance from the action of the flame, and would be occasionally attended with other disadvantages.

A. THE BLOWPIPE.

The best and most useful form of blowpipe is represented in Fig. 3 (see page 10), which is drawn to the scale of about half the size of the original. The tube and nozzle of the instrument are usually made of brass, German silver or silver, with a platinum point and a trumpetshaped mouthpiece of horn or ivory. Many blowpipes have no mouthpiece of this form, but are simply tipped with ivory or some similar material. The air chamber (A) serves in some small degree to regulate the blast, and receives the stem (B) and the nozzle (a), which are made separately

Fig. 3.



and accurately ground in that they may be put or taken apart at pleasure point (b) is best made num, to allow of its being cleaned, and is of the form in the woodcut.*

When the instrument the mouthpiece is pressed the lips, or if this be the end of the stem must be between the lips of the operator. The former mode is far less weary the latter, and whereas with the pet mouthpiece it is easy to get a continued blast of 5 or 10 (as is sometimes requisite in qualitative assaying), without it, it is impossible to sustain an unbroken blast of more than 2 or 3 minutes. While blowing, the operator breathes through his nostrils only, and the epiglottis as a valve, forces the air through the blowpipe by means of the cheek muscles only.

The following paragraph is from *Plattner's* "Probirkunst Löthrohre."

* Another form of blowpipe which, from experience, we confidently recommend, and which has the advantage

Beginners usually commit the fault that while blowing, they do not close at the right moment the passage between the windpipe and the mouth, but blow for a longer or shorter period from the lungs alone. This mode of blowing if persevered in is undoubtedly prejudicial to the health, and it is therefore advisable that a beginner in the use of the blowpipe should exercise himself in breathing regularly and audibly through his nose while keeping up a continuous blast by the muscles of the mouth, and continue this practice until he is able to do so without any perceptible exertion. In attempting this he will not probably be immediately successful, but a few days' persevering practice will enable him entirely to master this primary difficulty.

B. THE LAMP.

The construction of the lamp will be clearly understood from the inspection of the accompanying woodcut (Fig. 4, see page 12) which represents it about $\frac{1}{3}$ of its real size. The body of the lamp is constructed of brass or tinned iron, lacquered on the outside, and is moveable up and down the pillar (*S*), on which it is held fast by means of the

that described above, of greater simplicity and cheapness, is that of Dr. *Black*. It consists of a conical tube of japanned iron, the smaller end of which is held in the mouth, while the larger is furnished with a nozzle similar to that shown in the figure. In all cases however a platinum point is desirable, in as much as, when covered with soot (an unavoidable evil attending the use of an oil-lamp), it may be readily cleaned by a few moments exposure to the flame of a spirit-lamp.

screw (*c*). At the end (*C*) of the lamp is the socket containing the wick (*a*), which, when the lamp is not in

Fig. 4.



covered by a screw-cap to prevent the escape of t
At the other end is the feed-hole (*A*), which is clo
like manner by a screw-cap. The forms of the sock
the cap are shown in the smaller figures (*B*) (*a'*) (*C'*)

When the lamp is in use it is raised to such a

on the pillar as will allow the operator conveniently to rest his arms on the table, while with the right hand he holds his blowpipe to the flame and with his left the platinum, charcoal, or other support on which is the substance under examination. The best fuel for the lamp is pure rape or poppy oil, which affords a strong heat and a smokeless flame, if the wick be not too high. The flame of a wax-candle is far inferior in size and intensity to that of a lamp.*

C. SUPPORTS.

It is evident that for the support of substances submitted to the blowpipe flame, some infusible material must be employed. The following supports are those mostly used.

- * In a laboratory to which gas is supplied, a burner of the form shown in the accompanying figure, and which may be screwed on to a gas-stand instead of the ordinary argand

Fig. 5.



burner used in laboratory operations, will be found to answer extremely well as a blowpipe lamp, and it has the ad-

Charcoal.—The best kind of charcoal for blowpipe purposes is that of closely grained pine wood, free from knots ; and it should, when struck, give a clear sonorous ring. It should be cut by a small toothed saw into rectangular prisms of about 6 inches in length and from 1 to 2 inches in breadth, having a flat smooth surface at right angles to the rings of growth. It is this surface which is always to be used, and a good piece of charcoal may be made to serve for repeated experiments by simply filing off the used surface and exposing a new one after each operation. The substance to be subjected to the blowpipe flame, which, if in powder, should be previously moistened with a little water to make it cohere, is placed in a shallow hole scraped near one end of the charcoal, and the charcoal is so held that the flame may impinge upon it at an angle of about 20 degrees. The sides of the charcoal prism which are parallel, or rather tangential to the rings of growth, should not be used, as they burn unevenly, and from their structure are apt to split off and spoil the assay.

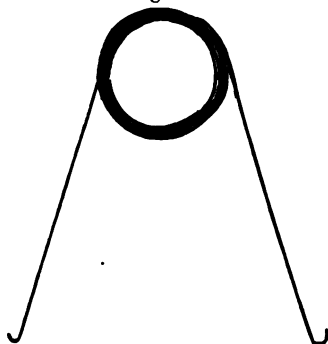
Charcoal is employed as a support when it is either required to reduce an oxidised substance or to fuse a body

vantage of dispensing with all the inconveniences of trimming, etc., which are necessarily attendant on the use of an oil-lamp. When a gas-flame is employed for blowpipe purposes, the oxidising and reducing flames are produced in the same way as in the case of the oil-lamp, but the reducing flame instead of being a bright yellow should be of the same blue color as the centre of the oxidising flame. When the oxidising flame is required, the assay should moreover be held at a considerable distance (viz. $\frac{1}{2}$ to $\frac{3}{4}$ of an inch) beyond the point of the visible flame.

without oxidising it ; also in many cases when it is desired to oxidise a body on which the reducing action of the charcoal alone is unimportant.

Platinum wire.—This should be of about $\frac{1}{1000}$ of an inch in diameter. It may be used in a coil with the ends unrolled, as shown in Fig. 6, in which case it is held

Fig. 6.



by passing the forefinger through the coil ; or, as is more convenient, it may be cut into lengths of about $1\frac{1}{2}$ to 2 inches each, and fixed in a holder similar to that used for crochet needles. One end of the wire is bent into a small hook as shown in

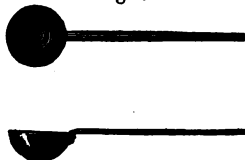
the figure, and in this the borax or microcosmic salt is placed and fused into a bead. Care must always be taken that no substances such as sulphur, lead, etc., which act upon platinum, be fused upon platinum wire.

Platinum Foil.—Platinum foil is employed as a support for substances which it is desirable not to expose to the reducing action of charcoal. It is used in pieces of about 2×1 inches, and is held either on a piece of charcoal or in a pair of forceps.

Platinum Spoon. — This should be of the size and

form shown in the woodcut (Fig. 7). It may either be

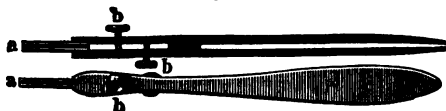
Fig. 7.



fixed into a handle, or, what answers equally well, may be stuck into a cork. It is used for the fusion of certain substances with potash, bisulphate of potash, and saltpetre.

A Pair of Brass Forceps with Platinum Tips.—These are constructed as shown in Fig. 8. A fragment of the mineral or other substance to be examined is held between

Fig. 8.



the platinum points (*a*), which are opened by pressing on the knobs (*b b*), and close again by their own elasticity. These forceps are used for holding splinters of minerals, etc., which are to be heated to ascertain their fusibility and the color they impart to the blowpipe flame. They are about 5 inches long.

Glass Tubes.—Tubes of about $\frac{1}{4}$ of an inch internal diameter, cut into lengths of 5 or 6 inches, and open at both ends. These are used especially for roasting substances containing sulphur, arsenic, selenium, antimony, tellurium, etc., which when heated with access of air evolve fumes which may be recognised by their color, odor, and chemical reactions.

Small Glass Bulbs, or, what answers equally well, glass tubes closed at one end, and about $2\frac{1}{2}$ or 3 inches long.

They serve to contain substances which are to be tested for water, mercury, sulphur, or other bodies which are volatilised by the application of heat without the access of air. The volatile products collect in the neck of the bulb or tube, and may be judged of by their color, odor, etc.

D. REAGENTS.

For most experiments with the blowpipe a very few reagents are requisite, and these only in limited quantities. The salts in common use, and of which the largest quantities are required, are :—Carbonate of Soda, Borax and Microcosmic Salt.

Carbonate of Soda,—which for convenience we shall term Soda, must be anhydrous and absolutely free from any admixture of the sulphate. It is employed principally to aid in the reduction of metallic oxides and sulphides on charcoal, to decompose silicates, and to determine the fusibility or infusibility of substances when heated with this salt.

Borax,—purified borax should be heated below the fusing point, to drive off its water of crystallisation, and then pulverised. When it is required to make a bead, in order that the powder may adhere to the platinum wire, the hooked end of the latter is heated and dipped into the borax. A small portion of the powder will be taken up, and this being fused and again dipped while hot into the powdered salt, a fresh portion will adhere, and this process is repeated until a bead of sufficient size is obtained. The bead thus formed should be clear and perfectly colorless

both in the hot and the cold state. While the glass is still hot and fluid, it is touched with a small quantity of the powder of the substance under examination, and that which adheres is fused into it. The operator must then observe ; first, whether the substance be soluble or insoluble in borax ; and, second, the color of the borax bead in (1.) the oxidising, and (2.) the reducing flame, both in the hot and in the cold state. In performing this experiment care must be taken not, in the first instance, to dissolve up too large an amount of the oxide or other substance under examination. If a small quantity affords no distinct reaction, more may be easily added. If however the color of the bead be too intense to be clearly distinguished, the bead may be jerked off the wire, and that which still adheres fused up with a fresh quantity of borax, by which a paler and more transparent glass will be obtained.

Microcosmic Salt,—or Phosphate of Soda and Ammonia $[\text{NaO}, \text{NH}_4\text{O}, \text{HO}] \text{PO}_3$. As this salt when fused is so fluid that it readily drops from platinum wire, it is desirable to fuse it in the first instance on charcoal or platinum foil, by which the water and a large proportion of the ammonia contained in it are expelled, and it becomes more viscid. Some of the glass thus formed is taken up on the platinum wire, and the powdered mineral or oxide is applied and fused into it as when operating with borax.

Besides the three principal reagents just described, the following are required in certain cases :—saltpetre, or nitrate of potash, for oxidising certain substances by fusing with them either on platinum foil or in the

platinum spoon ;—bisulphate of potash for eliminating certain volatile matters, as lithia, boracic acid, hydrofluoric acid, bromine, iodine, etc., as also for decomposing salts of titanic, tantallic and tungstic acids ;—nitrate of cobalt, chemically pure and in solution, for substantiating the presence of alumina, magnesia, oxide of zinc, oxide of tin and titanic acid, which, when moistened with this reagent and strongly heated, assume certain characteristic colors ;—silica, for various purposes ;—fluor spar (fluoride of calcium), which mixed with bisulphate of potash is used for ascertaining the presence of lithia and boracic acid ;—oxide of nickel or oxalate of nickel for the detection of potash in large quantity in salts which also contain soda and lithia ;—protoxide of copper for detecting chlorine, bromine and iodine ;—tin foil for reducing various metallic oxides dissolved in borax or microcosmic salt [the hot fluid bead is touched on charcoal with a piece of tin foil, and then strongly heated for some seconds under the reducing flame] ;—silver for discovering sulphur and sulphuric acid.

The reagents should be kept in small stoppered bottles, the stoppers being carefully ground so as to exclude the air. They may for convenience be fitted into a wooden stand, and if for travelling, may with the blowpipe apparatus be enclosed in a wooden or leather case, made so as to be easily portable.

In addition to the apparatus already described, the following articles are desirable, though with some exceptions not indispensable :—a small steel hammer ; an anvil, the most convenient form of which is a piece of rectangular steel about $1\frac{1}{2}$ inches long, $1\frac{1}{4}$ inches wide and $\frac{1}{2}$

an inch thick ; a steel crushing mortar ; some round and triangular files ; a pair of scissors ; a pair of forceps for trimming the lamp ; a magnet ; a pocket lens ; some porcelain capsules, and a spirit lamp.

II.

QUALITATIVE EXAMINATION WITH THE BLOWPIPE.

As in chemical analysis by the wet way, this consists in the performance of certain processes, the object of which is to ascertain the presence or absence of certain bodies, without regard to their relative quantities. These operations are most conveniently performed in the following order. — (1.) Examination of the substance in the glass bulb or tube closed at one end ; (2.) in the open tube ; (3.) on charcoal ; (4.) in the platinum forceps ; (5.) in the borax bead ; (6.) in microcosmic salt ; (7.) with carbonate of soda ; in addition to which it is frequently necessary to perform (8.) some other experiments in order to substantiate the presence of certain substances, the presence or absence of which has not been positively established by the previous processes.

1. EXAMINATION IN THE GLASS BULB.

The bulb or tube having been previously thoroughly cleaned and dried, a small fragment or portion of the

powder of the substance to be investigated is introduced into it and heated over a spirit-lamp, at first gently and then more strongly with the blowpipe, until the glass begins to soften. It is then to be observed :

(a.) Whether there is any sublimate or vapour collected in the neck of the bulb, as e. g. water, mercury, sulphur, selenium, tellurium, arsenic. The first three of these bodies are easily recognised by their well-known appearance. If there be any condensed moisture, it should be tested with a piece of litmus paper, to ascertain whether it gives an alkaline or acid reaction. When organic substances are present, they may be recognised by their peculiar empyreumatic odor. Quicksilver, when in very small quantity, can sometimes only be recognised by means of the lens, and the sublimate should in all cases be carefully examined with the aid of that instrument. Selenium gives a reddish brown sublimate, which has, if thick, a steel-grey color in the lower part. Tellurium affords a grey, and arsenic a black sublimate; the latter when in considerable quantity having moreover a metallic lustre.

In case of the non-appearance of any of these reactions, it must not be always concluded that the above-mentioned bodies are entirely absent; for sulphur, selenium, tellurium and arsenic may be present in such forms that the simple application of heat will either not sublime them or will expel them in combinations which afford none of the distinctive characters of the simple bodies. Moreover two or more of these may be present together in a substance, and afford sublimates having mixed characters, so that the individual elements are difficult to distinguish. Such is frequently the case with arsenic and

sulphur, which together form a coating on the tube having a metallic lustre at its lower extremity, and passing upwards successively into black, brown, red, and finally yellow, these colors being due to combinations of sulphur and arsenic which are more volatile than metallic arsenic. —Oxygen and ammonia when driven off by heat are to be recognised in the glass bulb by introducing in the former case a glowing splinter of wood, which immediately relights, in the latter a moist piece of red litmus paper, which is turned blue by the alkali. Very frequently however ammonia is not evolved in the free form, but in combination with an acid, in which case a white sublimate of the salt is obtained. In this case a fresh portion of the ammoniacal substance is to be mixed with caustic lime or soda, introduced into a clean bulb and heated, when free ammonia will be evolved.

There are some other bodies, as fluorine, chlorine, iodine, bromine and nitric acid, which may be recognised by heating in a bulb or closed tube; but as, in order to substantiate their presence, special experiments must be instituted, they will be spoken of more at length in another place.

(b.) Besides the variously colored sublimes afforded in the glass bulb, some other phenomena are occasionally exhibited, which aid materially in indicating the nature of a mineral substance, and should therefore be carefully noted. Such are changes of color, phosphorescence, decrepitation, etc. These appearances are however rather characteristic of certain minerals and mineral combinations than of their component elements, and will therefore be treated of in the second part of this little work.

As may be seen from the above, the examination of a substance in the glass bulb affords frequently no positive indication of the presence of a body, but merely intimates its probable existence, to establish which further investigations are necessary. Such intimations are however of importance as they serve as guides in after-processes.

2. EXAMINATION IN THE OPEN TUBE.

A small quantity of the powdered substance is introduced into the tube at about half an inch from its extremity and gradually heated, the tube being held in a slightly inclined position, so that a current of air may pass freely through it. By this means the substance is roasted or oxidised, and various matters contained in it are volatilised and pass off up the tube. Thus sulphur forms sulphurous acid, which is easily recognised by its strong pungent odor. Selenium is only slightly oxidised, but is volatilised and redeposited as a steel-grey sublimate in the cool part of the tube, affording at the same time the very characteristic smell of selenium vapour, which much resembles that of decayed horse radish.—Arsenic is volatilised as arsenious acid, antimony as antimonious acid, and tellurium as tellurous acid, all in the form of opaque white fumes. The white deposit formed by the first of these is distinctly crystalline, whereas the sublimates from the two latter are amorphous. Arsenious and antimonious acid may, when heated, be driven from one part of the tube to another, while tellurous acid fuses into small transparent drops, generally visible to the naked eye, and distinctly so when examined with the aid of the lens.

The roasting must be performed slowly, with a gradually increasing temperature, and with a good current of air passing through the tube, otherwise unoxidised matter may be volatilised and the mineral substance clotted and fused together. If a perfect roasting be required, the substance, after being heated for some minutes in the tube, is shaken out into an agate mortar, remixed, and roasted, and this process is repeated until fumes are no longer evolved.

3. EXAMINATION ON CHARCOAL.

In the examination of a substance on charcoal, the points to be noted are the same as those observed in the treatment in the glass bulb. It is of especial importance that the operator make himself thoroughly acquainted with the color and general appearance of the incrustation formed by various substances when heated on charcoal, a result best attained by experimenting in the first instance on chemically pure materials. The following paragraphs, extracted from the work of *Plattner* before mentioned, give a detailed description of the results afforded by various bodies.

Selenium

fuses easily, and gives off brown fumes both in the oxidising and the reducing flames. The deposit formed on the charcoal immediately around the assay is of a steel-grey color with a slightly metallic lustre, while that formed at a greater distance is of a dull violet color, passing at the edges into a reddish brown. By the application of the *oxidising flame* this deposit is easily driven from one part

of the charcoal to another, and under the reducing flame it leaves the charcoal with a beautiful blue flame. When either the assay or its sublimate is heated, it emits the characteristic smell already spoken of, resembling decayed horse radish.

Tellurium

fuses readily, volatilises under both flames with visible fumes, and covers the charcoal to within a small distance of the assay with a deposit of tellurous acid. This sublimate is white in the centre, and of a dark yellow towards the edges. It may be driven from place to place by the oxidising flame, but under the reducing it is entirely volatilised with a green flame, or, if selenium be also present, with a bluish green flame.

Arsenic

is volatilised without fusing, and covers the charcoal both in the oxidising and reducing flame with a coating of arsenious acid. This coating is white in the centre, and grey towards the edges, and is formed at some distance from the assay. By the most gentle application of the flame it is immediately volatilised, and if touched for a moment with the reducing flame, it disappears, tinging the flame pale blue. During volatilisation a strong garlic odor is distinctly perceptible, very characteristic of arsenic, and by which its presence in any compound may be immediately recognised.

Antimony

fuses readily, and coats the charcoal under both flames with antimonious acid. This incrustation is of a white color *where thick, but where thin* of a bluish tint, and is

formed nearer to the assay than that of arsenic. When gently heated with the oxidising flame, it is driven from place to place without coloring the flame ; but when volatilised with the reducing flame it tinges the flame blue. As antimonious acid is not so volatile as arsenious acid, they may thus be easily distinguished from one another.*

When metallic antimony is fused upon charcoal, and the metallic bead raised to a red heat, if the blast be suspended the fluid bead remains for some time at this temperature, giving off opaque white fumes, which are at first deposited on the surrounding charcoal and then upon the bead itself, covering it with white pearly crystals. This phenomenon is dependent upon the fact that the heated button of antimony in absorbing oxygen from the atmosphere develops sufficient heat to maintain the metal in a fluid state, until it becomes entirely covered with crystals of antimonious acid so formed.

Bismuth

fuses with ease, and under both flames covers the charcoal with a coating of oxide, which, while hot, is of an orange yellow color, and after cooling of a lemon yellow, passing at the edges into a bluish white. This white coating consists of the carbonate of bismuth. The sublimate from bismuth is formed at a less distance from the assay than is the case with antimony. It may be driven from place to place by the application of either flame ; but in so doing, the oxide is first reduced by the heated charcoal, and the

* For the reaction of antimonious acid with nitrate of cobalt, see p. 91.

metallic bismuth so formed is volatilised and reoxidised. The flame is uncolored.

Lead

fuses readily under either flame, and incrusts the charcoal with oxide at about the same distance from the assay as is the case with bismuth. The oxide is, while hot, of a dark lemon-yellow, but upon cooling becomes of a sulphur yellow. The carbonate which is formed upon the charcoal beyond the oxide is of a bluish white color. If the yellow incrustation of the oxide be heated with the oxidising flame, it disappears, undergoing changes similar to those of bismuth above mentioned. Under the reducing flame, however it disappears, tinging the flame blue.

Cadmium

fuses with ease, and in the oxidising flame takes fire and burns with a deep yellow flame, giving off brown fumes, which coat the charcoal to within a small distance of the assay with oxide of cadmium. This coating exhibits its characteristic reddish brown color most clearly when cold: where very thin, it passes into an orange color. As oxide of cadmium is easily reduced and the metal very volatile, the coating of oxide may be driven from place to place by the application of either flame, to neither of which does it impart any color. Around the deposit of oxide, the charcoal has occasionally a variegated tarnish.

Zinc

fuses with ease, and takes fire in the oxidising flame, burning with a brilliant greenish white flame, and forming thick white fumes of oxide of zinc, which coat the charcoal around the assay. This coating is yellow while hot, but when perfectly cooled becomes white. If heated with

the oxidising flame, it shines brilliantly, but is not volatilised, since the heated charcoal is under these circumstances insufficient to effect its reduction. Even under the reducing flame it disappears but very slowly.

Tin

fuses readily, and in the oxidising flame becomes covered with oxide, which by a strong blast may be easily blown off. In the reducing flame the fused metal assumes a white surface, and the charcoal becomes covered with oxide. This oxide is of a pale yellow colour while hot, and is tolerably brilliant when the oxidising flame is directed upon it. After cooling it becomes white. It is formed immediately around the assay, and cannot be volatilised by the application of either flame.

Molybdenum

in powder is infusible before the blowpipe. If heated in the outer flame, it becomes gradually oxidised and incrusts the charcoal at a small distance from the assay with molybdic acid, which near the assay forms transparent crystalline scales, and is elsewhere deposited as a fine powder. The incrustation, while hot, is of a yellow color, but becomes white after cooling. It may be volatilised by heating with either flame, and leaves the surface of the charcoal, when perfectly cooled, of a dark copper red color with a metallic lustre, due to the oxide of molybdenum which has been formed by the reducing action of the charcoal upon the molybdic acid. In the reducing flame metallic molybdenum remains unchanged.

Silver

when fused alone, and kept in this state for some time

under a strong oxidising flame, covers the charcoal with a thin film of dark reddish brown oxide. If the silver be alloyed with lead, a yellow incrustation of the oxide of that metal is first formed, and afterwards, as the silver becomes more pure, a dark red deposit is formed on the charcoal beyond. If the silver contains a small quantity of antimony, a white incrustation of antimonious acid is formed, which becomes red on the surface if the blast be continued : and if lead and antimony are both present in the silver, after the greater part of these metals has been volatilised, a beautiful crimson incrustation is produced upon the charcoal. This result is sometimes obtained in fusing rich silver ores upon charcoal.

Sulphides, Chlorides, Bromides and Iodides.

In blowpipe experiments it rarely occurs that we have to deal with pure metals which, if not absolutely nonvolatile, are recognisable by the incrustation they form upon charcoal. Some compound substances when heated upon charcoal form white incrustations resembling that afforded by antimony, and which, when heated, may in like manner be driven from place to place. Among these are certain sulphides, as sulphide of potassium and sulphide of sodium, which are formed by the action of the reducing flame upon the sulphates of potash and soda, and are, when volatilised, reconverted into those sulphates, and as such deposited upon the charcoal. No incrustation is however formed until the whole of the alkaline sulphate has been absorbed into the charcoal and has parted with its oxygen. As sulphide of potassium is more volatile than sulphide of sodium, an incrustation is formed from the former sooner than from the latter of these salts, and

is considerably thicker in the former case. If the potash incrustation be touched with the reducing flame, it disappears with a violet-colored flame, and if a soda incrustation be treated in like manner, an orange-yellow flame is produced.

Sulphide of lithium, formed by heating the sulphate in the reducing flame, is volatilised in similar manner by a strong blast, although less readily than the sulphide of sodium. It affords a greyish white film, which disappears with a crimson flame when submitted to the reducing flame.

Besides the above, the sulphides of lead and bismuth give, when heated in either flame, two different incrustations, of which the more volatile is of a white color, and consists in the one case of sulphate of lead, in the other of sulphate of bismuth. If either of these be heated under the reducing flame, it disappears; in the former case with a bluish flame, in the latter unaccompanied by any visible flame. The incrustation formed nearest to the assay consists of the oxide of lead or bismuth, and is easily recognised by its color when hot and after cooling. There are many other metallic sulphides which, when heated by the blowpipe flame, cover the charcoal with a white incrustation, as sulphide of antimony, sulphide of zinc and sulphide of tin. In all these cases however the incrustation consists of the metallic oxide alone, and either volatilises or remains unchanged when submitted to the oxidising flame.

Of the metallic chlorides there are many which, when heated on charcoal with the blowpipe flame, are volatilised and redeposited as a white incrustation. Among these are the chlorides of potassium, sodium, and lithium, which

volatilise and cover the charcoal immediately around the assay with a thin white film, after they have been fused and absorbed into the charcoal. Chloride of potassium forms the thickest deposit, and chloride of lithium the thinnest, the latter being moreover of a greyish white color. The chlorides of ammonium, mercury and antimony volatilise without fusing.

The chlorides of zinc, cadmium, lead, bismuth and tin first fuse and then cover the charcoal with two different incrustations, one of which is a white volatile chloride, and the other a less volatile oxide of the metal.

Some of the incrustations formed by metallic chlorides disappear with a colored flame when heated with the reducing flame: thus, chloride of potassium affords a violet flame, chloride of sodium an orange yellow, chloride of lithium a crimson, and chloride of lead a blue flame. The other metals mentioned above volatilise without coloring the flame.

The chloride of copper fuses and colors the flame of a beautiful blue. Moreover if a continuous blast be directed upon the salt, a part of it is driven off in the form of white fumes, which smell strongly of chlorine, and the charcoal is covered with incrustations of three different colors. That which is formed nearest to the assay is of a dark grey, the next dark yellow passing into brown, and the most distant of a bluish white color. If this incrustation be heated under the reducing flame, it disappears with a blue flame.

Metallic iodides and bromides behave upon charcoal in a similar manner to the chlorides. Those principally deserving of mention are the bromides and iodides of potassium and sodium. These fuse upon charcoal, are

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absorbed into its pores and volatilised in the form of white fumes, which are deposited upon the charcoal at some distance from the assay. When the saline films so formed are submitted to the reducing flame, they disappear, tinting the flame in the same manner as the corresponding chlorides.

4. EXAMINATION IN THE PLATINUM FORCEPS.

If the operator has convinced himself by a preliminary experiment that the substance under examination does not, when heated, attack platinum, a small splinter of it is to be taken between the platinum forceps and subjected to the oxidising flame; but if the substance is very fusible, a piece of platinum wire hooked at one end may be used instead of the forceps. If however the substance be one which exerts a chemical action on platinum, and would therefore injure the forceps wire, charcoal must be employed as support. In this examination not only the relative fusibility of a substance is ascertained, but a knowledge of the presence or absence of certain bodies which tinge the blue oxidising flame of various characteristic colors is also arrived at. Thus some bodies impart a yellow color to the flame, others violet, crimson, green or blue. In *Plattner's* "Löthrohrprobirkunst" the following details on this subject are given, the various substances being classed according to the color they produce in the flame.

Yellow.

Soda and its salts when heated on platinum wire in the point of the blue flame, possess the property of enlarging the outer visible flame and imparting to it an in-

tense orange-yellow color. Even when mixed with a considerable quantity of other salts, which also color the outer flame, the yellow of the soda is equally intense. In the same manner, when a small splinter of any silicate of soda is held in the platinum forceps to the point of the blue flame, it enlarges and colors the outer flame more or less according to its fusibility and the quantity of soda it contains. After prolonged blowing the yellow color does not disappear, but, on the contrary, becomes frequently more intense.

Violet.

Potash and the greater number of its salts, with the exception of the borate and phosphate, when heated on platinum wire, impart a violet color to the outer flame. If however even a trace of soda be present, although a pale violet tinge may be visible just beyond the assay, the remainder of the flame will be colored of an intense yellow by the soda. If the soda present amount to 1 or 2 per cent., there will be no perceptible coloration from the potash, as the whole of the flame will be intensely colored by the former alkali. The violet of potash salts becomes also imperceptible when lithia is present in any considerable proportion. Silicates which contain a large amount of potash only produce a violet color in the flame when they are entirely free from soda and lithia, and when they are easily fusible in small fragments.

Red.

There are three bodies which impart a red color to the exterior blowpipe flame, viz., lithia, strontia and

Lithia. — Lithia and its salts, especially the chloride, when fused on a platinum wire in the extremity of the blue flame, color the outer flame of a beautiful bright crimson. Even a considerable admixture of potash does not interfere with this color: at the utmost it becomes tinged with violet. Soda, on the other hand, even in small proportion, suffices to change the color to a yellowish red, and if present in considerable quantity, a reddish yellow is produced which is scarcely to be distinguished from the color afforded by pure soda salts.

Many lithia minerals, when fused in the forceps in the point of the inner blue flame, produce a red color in the outer flame. The lithium mica of Zinnwald in Saxony, e.g., affords a very characteristic lithia reaction; but the intensity of the color diminishes as soon as the mineral has been kept fused so long as to lose its fluidity. Some lithia minerals give a flame of more than one color, as Triphylline (a phosphate of lithium, iron and manganese), which affords a red flame surrounded by an outer green flame, the latter color being due to the phosphoric acid in the mineral. (See p. 37.) This result is best obtained by fusing a little of the powdered mineral on platinum wire: in the forceps it is obtained with difficulty, owing to the extreme fusibility of the mineral. In the same manner, if a small splinter of Amblygonite, a mineral consisting principally of phosphate of lithia and alumina, be fused in the point of the blue flame, a yellowish red color is imparted to the outer flame, surrounded by an orange yellow sheath due to a small amount of soda contained in the mineral. This coloration lasts as long as the mineral is kept fluid.

According to Turner, silicates of lithia, which when fused alone impart no color to the blowpipe flame, do so when mixed with fluorspar and bisulphate of potash and fused on platinum wire in the end of the blue flame. (See page 80.)

Strontia. — Chloride of strontium, when fused on platinum wire in the point of the blue flame, produces immediately an intense red color in the outer flame. Many other salts of strontia, as, e.g., the carbonate (Strontianite) and the sulphate (Celestine), when fused in the usual manner, afford in the first instance a pale yellow flame, which soon assumes the characteristic crimson of strontia. The presence of baryta interferes with this reaction.

Lime. — Chloride of calcium tinges the outer flame red, but not by any means so intensely as the chloride of strontium. Most pure calcspars and limestones produce at first a yellow colored flame, which becomes red when the carbonic acid has been driven off. Baryta interferes with this reaction of lime by partially neutralising the color of the flame. Fluorspar, while fusing, colors the outer flame red, as does a pure calcspar. Gypsum and Anhydrite give at first only a pale yellow color to the flame, which however soon changes to a red of no great intensity. The phosphate and borate of lime impart to the flame a green color unmixed with red. Of the silicates of lime, Tabular Spar alone colors the blowpipe flame characteristically red.

Green.

There are six bodies which produce a green color in the blowpipe flame, viz.: — baryta, molybdic acid, oxide of copper, telluric acid, phosphoric acid and boracic acid.

Baryta.—Chloride of barium fused on a platinum wire in the point of the blue flame produces a green color in the outer flame, which, at first of a pale tint, becomes, if the blast be continued, of an intense yellowish green. This result is best obtained by experimenting upon only a small quantity of the salt. The carbonate of baryta (Witherite) and the sulphate of baryta (Heavy Spar) color the flame, when heated strongly in the point of the blue flame. The color afforded by these salts is, however, by no means so intense as that produced by the chloride. The presence of lime does not interfere with the action of baryta, as may be proved by experimenting upon Barytocalcite, which consists of a double carbonate of lime and baryta. This mineral produces at first only a yellowish green color in the outer flame; but, when heated for a short time, the tip of the flame may be observed to have a red tinge more or less intense.

Molybdic Acid.—If a small quantity of either molybdic acid or oxide of molybdenum be taken up on the moistened end of a piece of platinum wire and submitted as usual to the point of the blue flame, a green colored flame is obtained exactly resembling that produced by baryta. If a thin plate of the native sulphide of molybdenum (Molybdenite) be held in the forceps and the edge heated in the blue oxidising flame, a similar coloration is produced, the mineral remaining unfused.

Oxide of Copper.—This oxide, both alone and in combination with acids which themselves produce no coloration in the blowpipe flame (as carbonic acid, acetic acid, etc.), affords an emerald green flame, when heated in the blowpipe flame in the usual manner. Metallic copper

also, when fused upon charcoal, and not perfectly protected from the contact of the atmosphere, becomes oxidised on the surface, and colors the blowpipe flame green. The combination of copper and iodine affords likewise an intensely green flame. Cupriferous lead ores color the outer blowpipe flame blue internally, and green externally and towards the point, the former color being due to lead. Cupriferous silicates, as Diopside and Chrysocolla, when heated in the forceps as already described, impart frequently an intensely green color to the outer flame. The same reaction is afforded by substances in which copper exists in small quantity only, if no other strongly coloring body be present.

Telluric Acid. — If telluric acid be submitted on platinum wire to the action of the blue flame in the usual manner, it fumes and colors the outer flame green. In like manner, if the incrustation of telluric acid formed upon charcoal by heating a fragment of a tellurium mineral, as already described, be reheated with the blue oxidising flame, it disappears with a green flame, if pure, or with a blue flame if selenium also be present.

Phosphoric Acid.—According to *Fuchs* and *Erdmann*, phosphoric acid and its salts, as well as minerals containing them, either when heated alone, or when having been previously moistened with sulphuric acid they are submitted to the blowpipe flame, produce a bluish green color in the outer flame. The reaction is so certain that, with proper care, a mere trace of phosphoric acid may be discovered in a substance, by mixing it in a powdered state with sulphuric acid, and heating a small quantity of the mixture in the hook of a platinum wire. This process is

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successful with many salts, which, when heated alone, do not manifest the characteristic reaction of phosphoric acid on account of the presence of soda or some other powerfully coloring substance. If the salt under examination contain water, this must first of all be expelled by heating upon charcoal, and the substance is then to be powdered, mixed with sulphuric acid and treated as above described. If soda be present, the flame will be colored distinctly green, until the phosphoric acid has been expelled by the sulphuric acid. As soon as this has taken place, the flame will assume the characteristic orange yellow of soda salts. As therefore the green flame lasts only for a few seconds, the flame must be carefully observed when the prepared substance is first introduced into it. Phosphate of lead and Pyromorphite, heated alone, give a blue flame with a constant green border.

Boracic Acid. — Boracic acid imparts a siskin green color to the outer flame, when heated in the usual manner on the hook of a platinum wire. If the acid be not perfectly free from soda, a more or less yellowish green flame is produced, and borax ($\text{NaO}, 2\text{BO}_3$) fused without the admixture of sulphuric acid, gives a yellow flame which conceals the boracic acid reaction. If, however, the salt be fused to expel the combined water, then pulverised and mixed with sulphuric acid, it affords, when exposed to the blowpipe flame, an intense green color which lasts until the whole of the boracic acid has been driven off. When minerals which contain boracic acid are treated in like manner with sulphuric acid, they all give a similar reaction. A modification of the above process for the detection of small quantities of boracic acid in minerals

has been proposed by *Turner*, as is described at page 84 of this work.

Blue.

The following bodies impart a blue color to the outer flame, when heated in the blue oxidising flame in the usual manner : — arsenic, antimony, lead, selenium and the combinations of copper with chlorine and bromine.

Arsenic.—Metallic arsenic and such metallic arsenides as have no other coloring body in combination, such, e.g., as Kupfernickel, Smaltine, etc., afford, when heated with the oxidising flame on charcoal, a clear blue flame. If moreover the arsenious acid which incrusts the charcoal, and which is very volatile, be rapidly heated with the flame, it disappears with a similarly colored flame. If such arseniates as emerald nickel, cobalt bloom, etc., the bases of which do not color the outer blowpipe flame, be heated in the platinum forceps, an intensely blue flame will be produced. Sometimes also the same results will be obtained with arseniates, the bases of which alone possess a considerable coloring power, as the arseniate of lime (Pharmacolite).

Antimony.—When metallic antimony is fused upon charcoal under the oxidising flame, the metallic bead is surrounded with an almost imperceptible blue flame. If the white incrustation of the oxide formed on the charcoal be subjected to the same flame, it disappears with a greenish blue colored flame.

Lead.—If metallic lead be fused in like manner upon charcoal, the bead is surrounded with a bright blue flame ; and if the oxide deposited upon the charcoal be

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subjected to the blue flame, while volatilising it colors the flame in a similar manner. Lead salts, of which the acids *per se* do not possess the property of coloring the blowpipe flame, impart an intense blue color to the flame, when fused either on platinum wire or in the forceps.

Selenium. — When selenium is fused on charcoal in the oxidising flame, it volatilises with an intense blue color. The sublimate formed on the charcoal behaves in like manner.

Chloride of Copper. — This salt, both native (Atacamite) and artificial, colors the blowpipe flame intensely blue, when fused on platinum wire. If the heat be maintained for some time, the flame assumes a greenish color due to oxide of copper.

Bromide of Copper. — This salt, treated in the same manner as the above, colors the flame at first greenish blue, and afterwards green, owing to the formation of oxide of copper.

Fusibility.

In order to test the fusibility of a mineral, a small splinter, having a sharp edge or point, should be broken off and held in the forceps at a short distance beyond the point of the inner blue flame, so that the sharp edge is strongly heated. If a gas-flame be employed, the mineral must be held somewhat further from the point of the blue flame than is necessary in the case of an oil-lamp, in order to prevent any reduction taking place which would materially interfere with the results. If a powdered substance is to be tested, or one which decrepitates when heated, and must therefore be previously pulverised, the following process may be resorted to. A small quantity

of the powder is made into a paste with water and spread upon a piece of charcoal. It is then dried and strongly heated with an oxidising flame, and it will generally cohere sufficiently to allow of its being taken up between the forceps and tested in the usual manner. Care must be taken that the substance, if a fusible one, and one which acts upon platinum, be not allowed to fuse down upon the platinum points of the forceps.

If a substance be infusible or only very slightly fusible in the oxidising flame, it may afterwards be submitted to the extremity of the reducing flame, since many substances infusible in the former become fusible on undergoing a partial reduction: such are the silicates of peroxide of iron, which are infusible in the oxidising flame, but which when converted into the magnetic silicates fuse with more or less ease.

According to their relative fusibility minerals may be classed as follows:

- I. Readily fusible to a bead.
- II. With difficulty fusible to a bead.
- III. Readily fusible on the edges.
- IV. With difficulty fusible on the edges.
- V. Infusible.

This classification, which has been proposed by *Plattner*, is very convenient from its simplicity, and will therefore be adopted in this little work, the Roman numerals being employed as above to indicate to which division a mineral belongs.

In testing the fusibility of a mineral substance it should be noticed whether, if fusible, a clear or opaque bead is obtained, also whether the substance changes color,

42 EXAMINATION IN THE PLATINUM FORCEPS.

becomes magnetic, or exhibits any phenomena of intumescence, ebullition, etc., all of which are useful characters in indicating the nature of the mineral.

Of the metallic oxides the following only are fusible in the oxidising flame, viz.:—the oxides of copper, lead, antimony and bismuth. The magnetic oxide of iron is slightly fusible in the reducing flame, but in the oxidising flame is converted into the peroxide and becomes infusible. The corresponding compound oxides, chromic iron (FeO , Cr_2O_3), titaniferous iron (FeO , Ti_2O_3), and Franklinite (FeO , ZnO , MnO), (Fe_2O_3 , Mn_2O_3), behave in the same manner. Moreover the peroxide of iron (specular iron) is rendered fusible in the reducing flame by losing a portion of its oxygen and becoming converted into magnetic oxide.

Metallic sulphides are with few exceptions readily fusible under the blowpipe flame; these exceptions are: sulphide of zinc (zinc blende), sulphide of molybdenum (molybdenite), and sulphide of manganese (alabandine).

Of the simple silicates, i.e. silicates with a single base, those of the alkalis are most fusible. The silicates of lime and those of magnesia are with few exceptions practically infusible, the most fusible being, according to *Berthier*, those in which, as in Wollastonite, the oxygen of the acid is double that of the base. Silicates of alumina are infusible.

Of the silicates of iron those of the protoxide and magnetic oxide are very fusible, but those of the peroxide are practically infusible. Consequently under the blowpipe flame the fusibility of a silicate of iron much depends upon whether it be submitted to the oxidising or the re-

ducing flame; for, as has been already mentioned, many silicates of iron infusible in the former become fusible and magnetic in the latter flame.

The fusibility of a compound silicate, i.e. a silicate containing two or more bases, depends upon that of the simple silicates of which it is composed, but is generally greater than the mean of these latter. Thus many silicates of lime and magnesia, and of lime and alumina, are more fusible than any of the simple silicates which enter into their composition.

It is evident that among the natural silicates the fusibility of different specimens, belonging to the same mineral species, may vary considerably, since in accordance with the laws of isomorphism a more fusible base may be replaced to a greater or less extent by one that is less fusible, and vice versa. Thus while some specimens of Olivine (MgO , FeO) SiO_2 , which contain a considerable proportion of iron, fuse to a bead under the blowpipe flame, others containing less of this oxide are almost infusible.

5. TREATMENT WITH BORAX.

As this examination serves especially to distinguish certain metallic oxides, it is necessary, if the substance under examination contains any unoxidised metals, to convert these by a preliminary roasting into oxides. Metals in the state of sulphides, arsenides, etc., not only are difficultly soluble in borax, but the reactions afforded by them are more or less different from those of the corresponding oxides. The roasting is performed on charcoal or in an open glass tube, and to obtain a perfect oxidation must

be repeated two or three times, the substance being re-ground and mixed in an agate mortar before each repetition of the process. In roasting sulphides or arsenides it is frequently advantageous to mix the powdered substance with charcoal powder or graphite previous to roasting, in order to obviate the formation of sulphates, arseniates, etc., which cannot be decomposed by the flame alone. Under similar circumstances the same treatment is requisite previous to testing a substance in microcosmic salt.

6. TREATMENT WITH MICROCOSMIC SALT.

In this, as in the preceding process, the principal points to be noted are the colors which the beads assume while warm and when cold, both in the oxidising and in the reducing flame. There are certain oxides which render the bead more or less opaque when the latter is submitted to an irregular flame produced by rapidly blowing a strong and weak blast alternately. This, for want of any better word, may be termed an intermittent flame, since the bead is alternately subjected to a cooling and a heating atmosphere. The same opaque appearance of the bead may be frequently produced by slowly reheating the cooled bead with a weak flame, or by passing it backwards and forwards through the blowpipe flame. If the bead contain a large dose of the oxide, it frequently assumes the opaque condition spontaneously on cooling.

Of the following tables of the behaviour of metallic oxides and certain metallic acids with borax and microcosmic salt, No. II. is extracted from the work of Prof. *Plattner*, already cited. In addition to this it has been thought desirable to add another table, No. I., in which

the various metallic oxides are arranged according to the colors they impart to borax and microcosmic salt respectively. Such a table is useful as an index to that which follows, and in which the behaviour of the various oxides, etc., is described more in detail. The alkalies are omitted in both tables, and the alkaline earths from table II., since both these groups of oxides give colorless beads. Some of the earths under certain circumstances give opaque white beads, and these are mentioned in table I.



TABLE I.

A. BORAX.

1. Oxidising flame.
2. Reducing „

B. MICROCOSMIC SALT,

1. Oxidising flame.
 2. Reducing „
-

A. BORAX.

1. Oxidising flame.

Color of Bead.	Substances which produce this color		
	in the hot bead.		in the cold bead.
Colorless.	Silica Alumina Oxide of Tin (11) Telluric Acid (34) Baryta Strontia Lime Magnesia Glucina Yttria Zirconia Thoria Oxide of Lanthanum (2)	In all proportions.	Silica Alumina Oxide of Tin (11) Telluric Acid (34) Baryta Strontia Lime Magnesia Glucina Yttria Zirconia Thoria Oxide of Lanthanum (2) " " Silver (16) Tantalie Acid (25) Niobic " (26) Pelopic " (27) Titanic " (24) Tungstic " (29) Molybdic " (30) Oxide of Zinc (8)
	Tantalie Acid (25) Niobic " (26) Pelopic " (27) Titanic " (24) Tungstic " (29) Molybdic " (30) Oxide of Zinc (8)	In small quantity only.	With intermittent flame opaque white.

TABLE I. A.

Yellow, orange red and reddish- brown.	" " Sodium (9), pale-yellow / Otherwise colorless. " " Lead (10), yellow " " Bismuth (12), orange " " Antimony (28), yellow " " Cerium (1), red " " Iron (6), dark-red " " Uranium (13), red " " Silver (16) Vanadic Acid (31), yellow Oxide of Chromium (32), dark red	Oxide of Cerium (1) with intern. flame opaque-white. Oxide of Iron (6), yellow. " " Uranium (13) with intern. flame opaque-yellow. Oxide of Silver (16) in large proportion, with intern. flame opaline. Vanadic Acid (31), yellow. Oxide of Nickel (7), reddish-brown. " " Manganese (4), red to violet.
Violet or Amethyst.	Oxide of Nickel (7) " " Manganese (4) " " Didymium (3)	Oxide of Didymium (3).
Blue.	Oxide of Cobalt (6)	Oxide of Cobalt (6). " " Copper (14), blue to greenish-blue.
Green.	Oxide of Copper (14)	Oxide of Chromium (32) with yellowish tinge.

TABLE I. A.

A. BORAX.

2. Reducing flame.

Color of Bead.	Substances which produce this color	
	in the hot bead.	in the cold bead.
Colorless.	Silica	Silica
	Alumina	Alumina
	Oxide of Tin (11)	Oxide of Tin (11)
	Baryta	Baryta
	Strontia	Strontia
	Lime	Lime
	Magnesia	Magnesia
	Glucina	Glucina
	Yttria	Yttria
	Zirconia	Zirconia
	Thoria	Thoria only when saturated
	Oxide of Lanthanum (2)	Oxide of Lanthanum (2)
	" " Cerium (1)	" " Cerium (1)
	Tantalic Acid (26)	Tantalic Acid (26)
	Oxide of Didymium (3)	Oxide of Didymium (3)
	" " Manganese (4)	" " Manganese (4)
	Niobic Acid (26)	Niobic Acid (26)
	Pelopic " (27)	Pelopic " (27)
	Oxide of Silver (16)	Oxide of Silver (16)
	" " Zinc (8)	" " Zinc (8)
	" " Cadmium (9)	" " Cadmium (9)
	" " Lead (10)	" " Lead (10)
	" " Bismuth (11)	" " Bismuth (11)
In small proportions.		In small proportions.
After long continued blowing.		After long continued blowing.
		With an intermittent flame opaque-white

TABLE I. A.

	Vanadic " (31)	Vanadic " (30).
Blue.	Oxide of Cobalt (6)	Oxide of Cobalt (6). Titanic Acid (24) with intern. flame opaque-blue.
Green.	Oxide of Iron (6) " " Uranium (13) " " Chromium (32)	Oxide of Iron (6), bottle-green. " " Uranium (13), bottle-green. " " Chromium (32), emerald-green. Vanadic Acid (31), emerald-green.
Opaque-grey. (The opacity generally be- comes distinct during cooling.)	Oxide of Silver (16) " " Zinc (8) " " Cadmium (9) " " Lead (10) " " Bismuth (12) " " Antimony (28) " " Nickel (7) Telluric Acid (34) Niobic " (26) Pelopic " (27)	Oxide of Silver (16) " " Zinc (8) " " Cadmium (9) " " Lead (10) " " Bismuth (12) " " Antimony (28) " " Nickel (7) Telluric Acid (34) Niobic " (26) Pelopic " (27)
Opaque-red and reddish- brown.	Oxide of Copper (14)	Oxide of Copper (14).

TABLE I. B.

Yellow, orange, red and brown.	" " Cadmium (9) " " Lead (10) " " Bismuth (12) " " Antimony (28) " " Silver (16) " " Cerium (1) " " Iron (5) " " Nickel (7) " " Uranium (13) Vanadic Acid (31) Oxide of Chromium (32)	quantity.	Oxide of Silver (16). " " Iron (5). " " Nickel (7). " " Uranium (13), yellowish-green. Vanadic Acid (31).
Violet or Amethyst.	Oxide of Manganese (4) " " Didymium (3)		Oxide of Manganese (4). " " Didymium (3).
Blue.	Oxide of Cobalt (6)		Oxide of Cobalt (6). " " Copper (14), to greenish-blue.
Green.	Molybdic Acid (30), yellowish-green. Oxide of Copper (14)		Molybdic Acid (30), pale yellowish-green. Oxide of Uranium (18), yellowish-green. " " Chromium (32), emerald-green.

TABLE I. B.

B. MICROCOSMIC SALT.

2. Reducing flame.

Color of Bead.	Substances which produce this color	
	in the hot bead.	in the cold bead.
Colorless.	Silica (only slightly soluble) Alumina Oxide of Tin (11) Baryta Strontia Lime Magnesia Glucina Ytria Zirconia Thorina Oxide of Lanthanum (2) " Cerium (1) " " Didymium (3) " " Manganese (4) Tantallic Acid (25) Oxide of Silver (16) " Zinc (8) " Cadmium (9) " " Lead (10)	Silica (only slightly soluble). Alumina. Oxide of Tin. Baryta Strontia Lime Magnesia Glucina Ytria Zirconia Thorina only when saturated Oxide of Lanthanum (2) " Cerium (1). " " Didymium (3). " " Manganese (4). Tantallic Acid (25). Oxide of Silver (16) " Zinc (8) " Cadmium (9) " " Lead (10)
	After long continued blowing.	With an intermittent flame opaque white. After long continued blowing.

TABLE I. B.

Yellow, red and brown.	<p>Tungstic acid (29), yellow Pelopie " (27), brown Ferruginous Titanic Acid, blood red " Niobic " " " Pelopie " " " Tungstic " " Vanadic Acid (31), brownish Oxide of Chromium (32), reddish</p>	<p>Pelopie Acid (27). Ferruginous Titanic Acid. " Niobic " " Pelopie " " Tungstic "</p>
Violet or Amethyst.	Niobic Acid (26) in large proportion	Niobic Acid (26) in large proportion. Titanic " (24).
Blue.	<p>Oxide of Cobalt (6) Tungstic Acid (29) Niobic " (26) in very large proportion</p>	<p>Oxide of Cobalt (6). Tungstic Acid (29). Niobic " (26) in very large proportion.</p>
Green.	<p>Oxide of Uranium (13) Molybdic Acid (30)</p>	<p>Oxide of Uranium (13). Molybdic Acid (30). Vanadic " (31). Oxide of Chromium (32).</p>
Opaque-grey. (The opacity generally be- comes distinct during cooling.)	<p>Oxide of Silver (16) " Zinc (8) " Cadmium (9) " Lead (10) " Bismuth (12) " Antimony (28) " Nickel (7) Telluric Acid (34)</p>	<p>Oxide of Silver (16). " Zinc (8). " Cadmium (9). " Lead (10). " Bismuth (12). " Antimony (28). " Nickel (7). Telluric Acid (34).</p>
Opaque-red and reddish- brown.	Oxide of Copper (14)	Oxide of Copper (14).

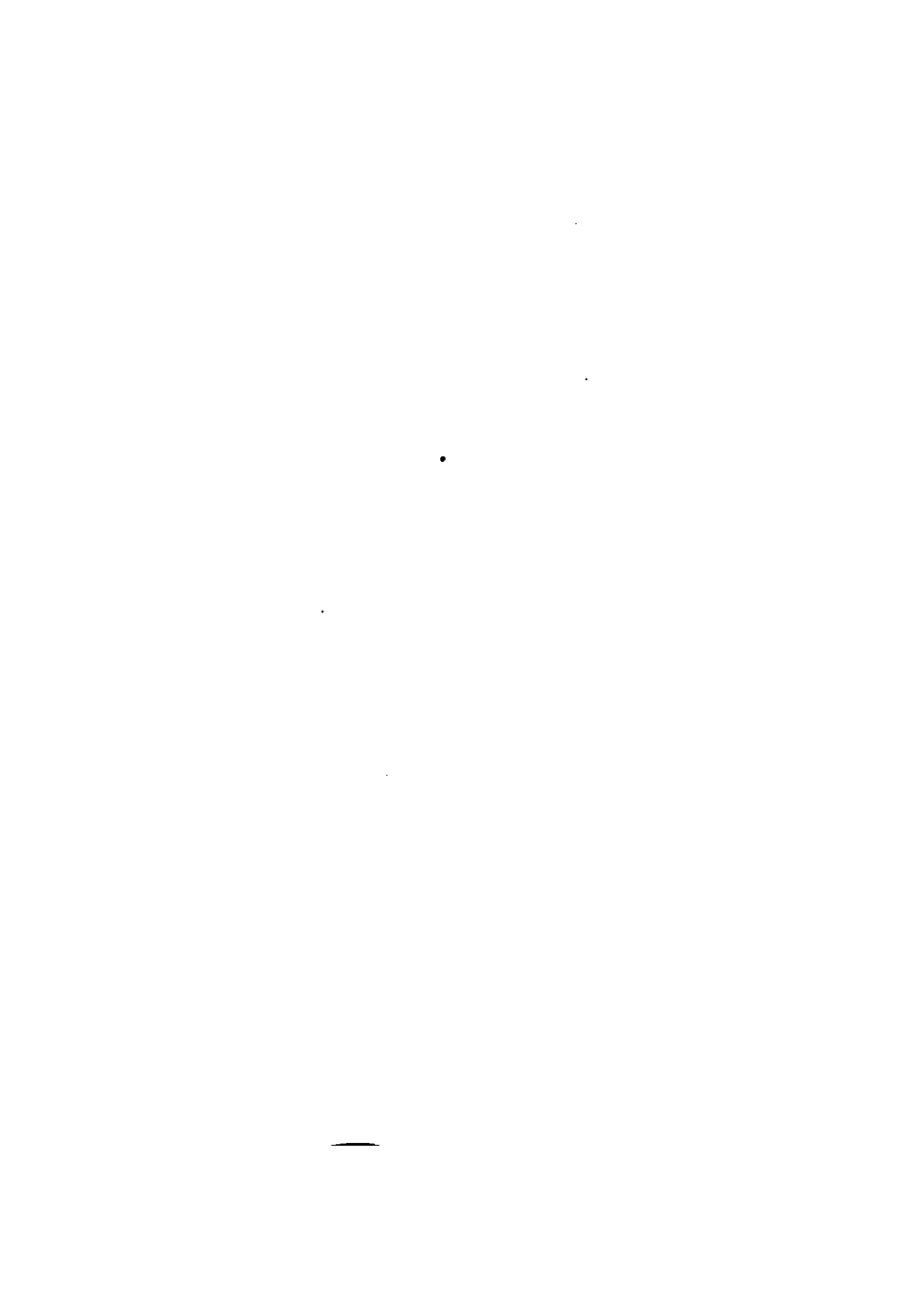


TABLE II.

TABLE II.

Metallic Oxide.	Behaviour with Borax on Platinum wire		Behaviour with Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
1) Oxide of Cerium, Ce_2O_3	Dissolves into a red or dark yellow glass (similar to that produced by iron). During cooling the color diminishes in intensity and becomes finally yellow. If much oxide be dissolved, an opaque bead may be obtained with an intermittent flame, and a still larger quantity renders it opaque spontaneously.	The color of the bead becomes paler; so that a bead, which is yellow in the oxidising flame, is rendered colorless. With a large quantity of oxide the bead becomes white and crystalline on cooling.	As with borax. During the process of cooling the color entirely disappears.	Both when hot and cold the bead is colorless, by which character oxide of cerium may be distinguished from oxide of iron. The glass remains clear even when containing a large quantity of the oxide.
2) Oxide of Lanthanum,	Dissolves into a colorless glass, which, when sufficient oxide is present, may be rendered	As in the oxidising flame.	As with borax.	No reaction.

TABLE II.

3) Oxide of Didymium, D_2O .	<p>IN WATER. A BEAD OF OXIDE IS DISSOLVED.</p> <p>Dissolves to a clear dark amethystine glass.</p>	No reaction.	As with borax.	No reaction.
<p>4) Oxide of Manganese, Mn_2O_3.</p>	<p>Affords an intense amethyst color, which on cooling becomes violet. A large quantity of the oxide produces an apparently black bead, which however, if pressed flat, is seen to be transparent.</p>	<p>The colored bead becomes colorless. With a large amount of the oxide, this reaction is best obtained upon charcoal, and is facilitated by the addition of tin foil.</p>	<p>With a considerable quantity of oxide an amethyst color is obtained, but never so dark as in borax. With but little oxide a colorless bead is obtained, in which however the amethyst color may be brought out by adding a little nitre. While the bead is kept fused, it froths and gives off bubbles of gas.</p>	<p>The colored bead immediately loses its color, either on platinum wire or on charcoal. After the reduction the fluid bead remains still.</p>

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
5) Oxide of Iron, Fe_2O_3 .	With a small proportion of oxide, the glass is of a yellow color while warm, and colorless when cold; with a larger proportion, red while warm, and yellow when cold; and with a still larger amount, dark-red while warm, and dark-yellow when cold.	Treated alone on platinum wire, the glass becomes of a bottle-green color (Fe_2O_3), and if touched with tin, it becomes of a pale sea-green. On charcoal with tin, it assumes at first a bottle-green color, which by continued blowing changes to a sea-green (FeO).	With a certain amount of oxide, the glass is of a yellowish-red color, which on cooling changes to yellow, then green, and finally becomes colorless. With a large addition of oxide the color is, when warm, dark red, and passes, while cooling, into brownish-red, dark green, and finally brownish-red. During the cooling process the colors change more rapidly than with borax.	With a small proportion of oxide there is no reaction. With a larger amount the bead is red while warm, and becomes on cooling successively yellow, green and russet. With the addition of tin the glass becomes, during cooling, first green, and then colorless.

TABLE II.

no. of experiment	Diagn.	7) Oxide of Nickel, Ni O.	Colors intensely. A small amount of oxide affords a glass which, while warm, is violet and becomes of a pale reddish-brown on cooling. A larger addition produces a dark violet color in the warm and reddish-brown in the cold bead.	The oxide is reduced and the metallic particles give the bead a turbid grey appearance. If the blast be continued, the metallic particles fall together without fusing, and the glass becomes colorless. This reaction is readily obtained with tin upon charcoal, and the reduced nickel fuses to a bead with the tin.	Dissolves into a reddish glass, which becomes yellow on cooling. With a large addition of the oxide, the glass is brownish while hot, and orange when cold.	On platinum wire the nickeliferous bead undergoes no change. Treated with tin upon charcoal, it becomes grey, and after long continued blowing the reduced nickel forms a bead, and the glass remains colorless.
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TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
8) Oxide of Zinc. Zn O.	Dissolves easily into a clear colorless glass, which, when much oxide is present, may be rendered opaque and flocculent by an intermittent flame, and becomes so spontaneously with a still larger addition. When a considerable quantity is dissolved, a glass is obtained, which is pale-yellow while hot, and colorless when cold.	On platinum wire the saturated glass becomes at first opaque and grey, but by a sustained blast is again rendered clear. On charcoal the oxide is gradually reduced; the metal is volatilised, and incrusts the charcoal with oxide.	As with borax.	As with borax.
	When in very large proportion dissolves to a clear yellow glass,			On charcoal the oxide is slowly and imperfectly reduced. The

TABLE II.

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Cd O.	Dissolves readily to a clear yellow glass, which loses its color upon cooling, and when containing much oxide can be rendered dull under an intermittent flame. With a still larger addition of oxide it becomes opaque yellow on cooling.	YELLOW OXIDE.	SOURCE MILLS-WILSON.	SUMMATION OF THE REACTIONS the reaction.
10) Oxide of Lead, Pb O.	<p>The plumbiferous glass spreads out on charcoal, becomes turbid, bubbles up, until the whole of the oxide is reduced, when it again becomes clear. It is however difficult to bring the lead together into a bead.</p>	<p>As with borax, but a larger addition of oxide required to produce a yellow color in the warm bead.</p>	<p>On charcoal the plumbiferous glass becomes grey and dull. With an overdose of oxide a part is volatilised and forms an incrustation on the charcoal beyond the bead. The addition of tin does not render the glass opaque, but somewhat more dull and grey than in its absence.</p>	

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
11) Oxide of Tin, Sn O_2 .	In small quantity dissolves slowly into a clear colorless glass, which, when cold, remains clear, and cannot be rendered opaque with an intermittent flame. If a saturated bead, which has been allowed to cool, be reheated to incipient redness, it loses its rounded form and exhibits imperfect crystallization.	A glass containing but little oxide undergoes no change. If much of the latter be present, a part may be reduced upon charcoal.	In small quantity dissolves very slowly to a colorless glass, which remains clear on cooling.	The glass undergoes no change either on charcoal or platinum wire.
	Dissolves readily to a clear glass, which with a small amount of the oxide is yellow while warm, and becomes	The glass becomes at first grey and turbid, then begins to effervesce, which action continues during the	Dissolves in small quantity to a clear colorless glass. A larger addition affords a glass which, while warm, is yellow, and becomes	On charcoal, and especially with the addition of tin, the glass re-

TABLE II.

<p>becomes opaline in process of cooling.</p>	<p>but when the metal is collected into a bead, the glass is again clear and colorless.</p>	<p>addition of oxide renders the bead spontaneously opaque on cooling.</p>	<p>The glass assumes a beautiful green color, which becomes more brilliant as the bead cools. The addition of tin upon charcoal produces no further change.</p>
<p>Behaves similarly to oxide of iron, with the exception that the color of the former is somewhat paler. When sufficiently saturated, the glass may be rendered of an opaque yellow by an intermittent flame.</p>	<p>Affords the same color as the oxide of iron. The green glass obtained in this flame, if sufficiently saturated, can be rendered black by an intermittent flame, but it has under these circumstances no enamel appearance. On charcoal, with the addition of tin, the glass takes a dark green color.</p>	<p>Dissolves to a clear yellow glass, which assumes a yellowish-green color on cooling.</p>	
<p>13) Oxide of Uranium, U_2O_3.</p>			

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
14) Oxide of Copper, Cu O.	Produces an intense coloration. If in small quantity, the glass is green while warm, and becomes blue on cooling. If in large proportion, the green color is so intense as to appear black. When cool this becomes paler and changes to a greenish-blue.	If not too saturated, the cupriforous glass soon becomes nearly colorless, but immediately on solidifying assumes a red color and becomes opaque. By long continued blowing on charcoal, the copper in the bead is reduced and separates out as a small metallic bead, leaving the glass colorless. With the addition of tin the glass becomes of an opaque dull-red on cooling.	With an equal proportion of oxide, this salt is not so strongly colored as borax. A small amount imparts a green color in the warm and a blue in the cold. With a very large addition of oxide, the glass is opaque in the hot state, and after cooling of a greenish-blue.	A tolerably saturated glass assumes a dark green color under a good flame, and on cooling becomes of an opaque brick-red the moment it solidifies. A glass containing but a small proportion of the oxide becomes equally red and opaque on cooling, if treated with tin upon charcoal.
15) Oxide of				

TABLE II.

16) Oxide of Silver, Ag O.	quantity it colors the glass yellow while warm, the color disappearing on cooling. In larger quantity the glass is yellow while warm, but during cooling becomes paler to a certain point and then again deeper. If reheated slightly the glass becomes opalescent.	On charcoal the argentiferous glass becomes at first grey from the reduced metal, but afterwards, when the silver is collected into a bead, it becomes clear and colorless.	Both the oxide and the metal afford a yellowish glass, which when containing much oxide becomes opaline, exhibiting a yellow color by daylight and a red one by artificial light.	As with borax.
17) Oxide of Platinum, Pt O ₂ .	Are reduced without being dissolved. The reduced metal, being infusible, cannot however be collected into a bead.	As in the oxidising flame.	As in borax.	As in borax.
18) Oxide of Palladium, Pd O ₂ .				
19) Oxide of Rhodium, Rh O ₃ .				
20) Oxide of Iridium Ir ₂ O ₃ .				

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
21) Oxide of Ruthenium, Ru_2O_3 .				
22) Oxide of Osmium, OsO_2 .				
23) Oxide of Gold, Au_2O_3 .	Is reduced without being dissolved, and can be collected into a bead on charcoal.	As in the oxidising flame.	As in borax.	As in borax.
	Dissolves readily to a clear glass, which, when hot little acid is pre-			The glass obtained in the oxidising flame becomes yellow in the hot state, but on cooling assumes a beautiful violet color. If too saturated this color is

TABLE II.

25) Tantalio Acid, TaO_5 .	<p>condition of the acid be- comes so spontaneously on cooling.</p> <p>Dissolves readily to a clear colorless glass, which, when sufficiently saturated, may be ren- dered opaque with an intermittent flame, and with a larger addition of the acid becomes spontaneously enam- ine on cooling.</p>	<p>the glass then becomes violet.</p> <p>Dissolves readily to a clear glass, which, when it contains a large pro- portion of the acid, is yellow while warm, but becomes colorless on cooling.</p> <p>As in the oxidising flame.</p>	<p>The glass obtained in the oxidising flame undergoes no change, nor does it, according to <i>H. Rose</i>, alter by the addition of sul- phate of iron.</p>
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TABLE II.

Metallic Oxides.	Behaviour with Borax on Platinum wire		Behaviour with Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
26) Niobic Acid, Ni_2O_3 .	Behaves in a similar manner to tantalic acid, but the glass requires a very large dose of the acid to render it opaque under an intermittent flame. With an increased amount of the acid, the glass is clear and yellow while warm, but on cooling becomes turbid, and when quite cold is white.	The glass obtained in the oxidising flame and which has become opalescent on cooling is rendered clear in the reducing flame. With a larger addition of the acid, it becomes dull, and of a bluish-grey color on cooling, and a still larger amount renders it opaque and bluish grey.	Dissolves in large quantity to a clear colorless glass.	If the acid be not present in too large a proportion, the glass remains unchanged. An additional amount of the acid renders it violet, and a still larger quantity affords a beautiful pure blue color, similar to that produced by tungstic acid. If to such a bead some sulphate of iron be added, the glass becomes blood-red. The addition of peroxide of iron renders the glass deep yellow while warm, the color becoming paler on

TABLE II.

<p>27) Pelopie Acid, Pb_3O_5.</p>	<p>Behaves similarly to the preceding.</p>	<p>A bead containing sufficient of the acid to render it spontaneously opaque on cooling has a greyish color.</p>	<p>Dissolves even in large quantity to a colorless glass.</p>	<p>With a sufficient of the acid, the glass becomes brown with a violet tinge. This reaction is readily obtained upon charcoal. Sulphate of iron renders the bead blood-red.</p>
<p>28) Oxide of Antimony, Sb_2O_3</p>	<p>Even when in large proportion dissolves to a clear glass, which is yellow while warm, but almost entirely loses its color on cooling. On charcoal the antimonious acid may be almost expelled, so that tin produces no further change.</p>	<p>A bead that has only been treated for a short time in the oxidising flame, when submitted to the reducing flame, becomes grey and turned from the reduced antimony. This soon volatilises and the glass again becomes clear. The addition of tin renders the glass ash-grey or black according to the amount of oxide it contains.</p>	<p>Dissolves with ebullition to a glass of a pale yellow color while warm.</p>	<p>On charcoal the saturated glass becomes at first dull, but as soon as the reduced antimony is volatilised, it again becomes clear. With tin the glass is at first rendered grey by the reduced antimony, but by continued blowing is restored to clearness. Even when the glass contains but little oxide, tin produces this reaction.</p>

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
29) Tungstic Acid, $W O_3$	<p>Dissolves readily to a clear colorless glass. In large proportion it renders the borax yellow while warm, and with a still greater addition the bead may be made opaque with an intermittent flame. If more be then added, this reaction takes place spontaneously.</p>	<p>When the oxide is present in small quantity, the glass undergoes no change. With a larger proportion, the glass is deep yellow while warm, and yellowish-brown when cold. This reaction takes place upon charcoal with a small quantity of the acid. Tin produces a dark coloration when the acid is not present in too great quantity.</p>	<p>Dissolves to a clear glass which, when saturated, is yellow in the hot state.</p>	<p>The glass is of a pure blue. If the tungstic acid contain iron, the glass becomes blood-red on cooling, similar to titanite acid. In this case tin restores the blue color, or if iron be in considerable quantity, renders it green.</p>
	Dissolves readily and in	The glass, which has been treated in the		

TABLE II.

<p>renders it yellow when warm, the color on cooling changing first to a pale enamel blue, and then to an enamel white.</p>	<p>is visible in the yellow glass in the form of black flakes. If the glass appear opaque, it should be flattened with the forceps.</p>	<p>charcoal the glass becomes dark, and when cool has a beautiful green color.</p>	<p>action on charcoal is precisely similar. Tin renders the color somewhat darker.</p>
<p>Dissolves to a clear glass, which is colorless when only a small quantity of acid is present, and yellow when containing a larger portion.</p>	<p>The yellow color of the glass changes to a brown when warm, and a chrome green on cooling.</p>	<p>As with borax.</p>	<p>As with borax.</p>

31) Vanadic
Acid,
 V_2O_5

TABLE II.

Metallic Oxides.	Behaviour in Borax on Platinum wire		Behaviour in Mic. Salt on Platinum wire	
	in the oxidising flame.	in the reducing flame.	in the oxidising flame.	in the reducing flame.
32) Oxide of Chromium Cr_2O_3 .	Affords an intense color, but dissolves slowly. A small proportion colors the glass yellow when warm, and yellowish green when cold; a larger addition produces a dark red color when warm, which, on cooling, becomes yellow, and finally a brilliant green with a tinge of yellow.	A small quantity of the oxide renders the glass beautifully green both when warm and when cold. A larger addition changes it to a darker emerald green. Tin produces no change in the color.	Dissolves to a clear glass, which has a pink tinge while warm, but on cooling becomes dusky green, and finally brilliantly green.	As in the oxidising flame except that the colors are somewhat darker. Tin produces no further change.
33) Arsenious Acid, As_2O_3 .	No reaction.	No reaction.	No reaction.	No reaction.
34) Tellurous Acid, TeO_2 .	Dissolves to a clear colorless glass, which when treated on charcoal becomes grey and dull from particles of	As in the oxidising flame.	As with borax.	As with borax.

7. EXAMINATION WITH CARBONATE OF SODA.

The substance under examination is pulverised and mixed with a certain proportion of carbonate of soda, moistened with water to make the mixture cohere, and a small portion placed upon the charcoal. This is gently heated at first until all the water has been driven off, and the heat is then raised as high as possible. The operator should then observe: 1st, whether the substance so treated fuses with effervescence: 2nd, whether it undergoes reduction: or 3rd, whether neither of these reactions takes place; in which case the alkali will be absorbed into the charcoal, and the substance remain on the surface unchanged.

The following substances fuse with effervescence: silica, titanio acid, tungstic acid and molybdic acid. Of these, silica and titanio acid fuse into a bead, the former only affording a bead which remains clear on cooling, and when the alkali has not been added in excess: the latter forms a bead, which on cooling becomes opaque and crystalline. Tungstic acid and molybdic acid are absorbed into the charcoal in the form of tungstate and molybdate of soda respectively. Baryta and strontia also fuse with carbonate of soda, and are absorbed into the pores of the charcoal, whereas lime is not.

When mixed with carbonate of soda and exposed upon charcoal to the reducing flame, the following metallic oxides are wholly or partially reduced: the oxides of the noble metals, and the oxides and acids of molybdenum, tungsten, antimony, arsenic, tellurium, copper, mercury, bismuth, tin, lead, zinc, cadmium, nickel, cobalt and iron. Of these, arsenic and mercury volatilise as soon as they are reduced,

76 EXAMINATION WITH CARBONATE OF SODA.

and occasionally leave scarcely any visible incrustation on the charcoal. Antimony, tellurium, bismuth, lead, zinc and cadmium are partially volatilised, and form distinct incrustations, the unvolatilised portion of the metal being found either fused or unfused in the soda. This latter portion will be best obtained by breaking off the surface of the charcoal beneath the assay, and subjecting it to careful pulverisation and levigation in an agate mortar. The metallic particles remain in the bottom of the mortar, if malleable, as little shining flakes, if brittle, in the form of a shining metallic powder. *Plattner* recommends the use of oxalate of potash instead of carbonate of soda for the reduction of the difficultly reducible metals.

With regard to the behaviour of silicates when fused with carbonate of soda, *Plattner* makes the following remarks: When silicates are treated with carbonate of soda the former give over a portion of their silica to the alkali and form fusible basic silicates. If more carbonate of soda be then added, the weaker bases are set free, and the mass becomes infusible. If the silicate be such that the oxygen of the silica is at least twice that of the base, when a sufficient amount of carbonate of soda is added, a clear glass is formed which remains clear on cooling. If, on the other hand, the oxygen of the silica be equal to that of the base, the silicate will be generally decomposed with the evolution of carbonic acid, but it will not fuse to clear glass, since the double silicate so formed is comparatively infusible. Fusible silicates, the bases of which are infusible in the uncombined state, form, with a small quantity of carbonate of soda, a clear glass, which becomes opaque on a further addition of the alkali, and is rendered

infusible by a still larger amount, a portion of the base being set free by the soda.

A mere trace of sulphur in a substance, whether existing as a sulphide, a sulphate, or any other combination, may be detected by fusing a portion of the substance under examination with 2 or 3 parts of carbonate of soda, or oxalate of potash, on charcoal, under the reducing flame. When the mass is thoroughly fused and the excess of alkali has been absorbed into the pores of the charcoal, the saturated portion of the latter with the fused mass is broken off and placed upon a piece of polished silver with a drop of water. If the smallest trace of sulphur be present, a black stain of sulphide of silver will appear on the surface of the silver. If this reaction do not readily appear, a drop of hydrochloric acid may be added to hasten it. For the mode of distinguishing sulphur and sulphuric acid see p. 85.

Another purpose for which carbonate of soda is employed, is the detection of traces of manganese in any combination. A mixture of the substance with carbonate of soda and a small quantity of saltpetre is fused in the oxidising flame on platinum foil: a greenish mass is thus obtained which assumes a turquoise blue color on cooling, this color being due to manganate of soda formed during the fusion.

8. SPECIAL EXPERIMENTS.

By the preceding course of investigation it is not always possible to establish with certainty the presence of certain bodies, the reactions of which are more or less obscured by the presence of other bodies. For this purpose

some further experiments are necessary, which are detailed in the following paragraphs.

Potash.—In substances which in addition to potash contain so much soda or lithia that the potash reaction in the outer oxidising flame is not perceptible, the presence of this alkali, when in considerable amount, may be ascertained by fusing a portion of the substance in a borax bead which has been colored by the oxide of nickel, and to which also a little boracic acid has been added. If the bead on cooling presents a bluish tinge, this may be regarded as an indication of the presence of potash. As the reaction depends on the amount of potash present, in case it be not obtained upon a first trial, additional portions of the substance must be successively added, and the experiment repeated. The oxidising flame alone is to be employed.

As the above process is at best an uncertain one, and altogether fails if potash be not present in very considerable quantity, it is generally desirable, when accurate results are required, to have recourse to a small analysis by the wet way. If the substance suspected to contain potash be soluble in water or in hydrochloric acid, a small quantity (2 or 3 grains), previously pulverised, is dissolved in one of these solvents in a porcelain capsule. If silica be present, the solution must next be evaporated to dryness and the residue heated to a temperature of about 250° to render the silica insoluble, after which a few drops of hydrochloric acid are added, and the residue, with the exception of the silica, dissolved in hot water. The silica having been separated by filtration, to the filtrate a solution of caustic baryta is added until the liquid is set

sibly alkaline. The metallic oxides and part of the alkaline earths will thus be precipitated, and may be separated by filtration. To the filtrate carbonate of ammonia is added to precipitate the excess of baryta and the remaining portion of alkaline earths, and the precipitate having been removed by filtration, the filtrate is evaporated to dryness with hydrochloric acid, and then heated to drive off the chloride of ammonium until fumes cease to be evolved. Finally, the alkaline residue is dissolved in a small quantity of water, and some alcohol and a few drops of chloride of platinum added, when, if potash be present, a crystalline orange-colored precipitate will be observable after a longer or shorter period, according to the quantity of the alkali.

If the mineral under investigation be free from silica, the process for the separation of that body may be dispensed with, and caustic baryta added directly to the hydrochloric acid solution of the mineral.

If a silicate insoluble in hydrochloric acid is to be examined for potash, it must, previous to being treated as above described, be finely pulverised and fused with about twice its bulk of carbonate of soda, free from potash, or, if this be not obtainable, with the same quantity of caustic baryta, in the platinum spoon. If baryta be used, only a small portion of the mixture can be treated at once, and a very strong flame is requisite. The flame must be directed upwards upon the outside of the spoon, and must not be brought into contact with the mixture. The fused, or if baryta be used, the fritted mass thus obtained, is dissolved in boiling water containing a few drops of

hydrochloric acid, and the solution treated in the same manner as that of a soluble silicate.

Lithia. — Silicates which contain but a small amount of lithia, as e.g. Lithia Tourmaline and some Scapolites, scarcely impart any red color to the outer flame. In such cases *Turner's* method should be applied, by which very small quantities of the above-mentioned earth may be detected. It is as follows: The silicate to be examined is finely powdered and mixed into a paste with a mixture consisting of one part of fluor-spar, $1\frac{1}{2}$ parts of bisulphate of potash, and one or two drops of water. A small portion of this is placed on the hooked end of a platinum wire, and fused with the point of the blue oxidising flame, the outer flame being carefully observed during the fusion. According to Merlet, to 1 part of the silicate, 2 parts of the above mixture should be added in order to obtain reliable results. If the silicate contain lithia even in very small proportion, the outer flame will be colored red, having however a slight tinge of violet, due to the potash. If, on the other hand, the silicate be free from lithia, a violet flame only will be obtained. If soda be present, the reaction cannot be relied upon; and if boracic acid be present, as in the case of Tourmaline, a green flame will be first of all produced, indicating the presence of that acid, and when this is volatilised, the lithia reaction will be obtained.

Lithia may be detected in the presence of soda by moistening the substance to be tested in hydrochloric acid, dipping it into melted wax or tallow, and then submitting it to the blowpipe flame. A red flame will be

perceptible for the first instant, but as soon as the wax or tallow is consumed the soda reaction predominates.

Manganese. — Very small quantities of manganese, even less than 0.1 %, may be detected in a substance by fusing 1 part of it in fine powder with 2 parts by volume of carbonate of soda and 1 part of saltpetre in the oxidising flame upon platinum foil. The fused mass will be colored more or less intensely greenish blue by the manganate of soda so formed.

Iron. — When oxide of iron exists in a mineral together with other metallic oxides, which conceal or modify its color in borax and microcosmic salt, further treatment is necessary in order either to separate these oxides, or to obtain them in such a form that they shall not interfere with the iron reaction.

If manganese be present, so that the borax bead has a deep violet color in the oxidising flame, by treating for a few seconds in the reducing flame the bead will be generally so far discolored as to exhibit clearly the bottle-green color of the magnetic oxide of iron. In case the quantity of manganese present is such that this is insufficient to effect its entire reduction, the bead must be treated on charcoal with tin foil, and under a strong reducing flame, until the manganese color has entirely disappeared, and the characteristic pale sea-green color of the protoxide of iron is clearly visible.

If copper, nickel or cobalt be present with iron, the borax bead containing the mixed oxides should be treated on charcoal with a small piece of metallic lead, under a strong reducing flame, until all the copper and nickel and a portion of the cobalt have separated out in the metallic

form and have alloyed with the lead. The borax bead is then to be removed from the charcoal, the metallic bead separated, and the former treated on the platinum wire in the oxidising flame. Then, if nickel or copper alone were present, the bead will afford a pure iron reaction; but if these oxides were accompanied by cobalt, the borax bead will appear green in the hot state, and, on cooling, will assume a bluish green or blue color, according to the relative proportions of the two oxides of cobalt and iron.

In chromic iron, chrome ochre, and other minerals containing oxide of chromium in combination with oxide of iron, the latter oxide may be detected by fusing a portion of the mineral in fine powder with 1 part of carbonate of soda and 3 parts of nitre, in the platinum spoon, or in several portions on a piece of platinum wire. By this means the oxide of chromium (Cr_2O_3) will be converted into chromic acid (CrO_3), which, combining with the alkalis present, forms a soluble chromate. If the fused mass be then dissolved in water, the insoluble peroxide of iron will separate out and may be tested by itself in borax on platinum wire.

Nickel and Cobalt.—When these two metals are present together in a substance, the color imparted by the cobalt to the borax bead is generally so intense as entirely to conceal that of the nickel. In order therefore to ascertain the presence of nickel under these circumstances, two or three borax beads are to be strongly colored with the mixed oxides, and placed, together with a small bead of gold weighing from $\frac{3}{4}$ of a grain to 1 grain, in a cylindrical hole in a piece of charcoal. The whole is then to be submitted to a strong reducing flame until all the nickel

has been reduced to the metallic state and has become alloyed with the gold bead. When this is accomplished, if the reduction be continued, a portion of the cobalt will also be reduced and pass into the gold, and as this generally takes place, the next process is to remove the cobalt. The gold bead, having been allowed to cool, is removed from the charcoal, separated from the adhering borax by a blow with the hammer, and, if necessary, by washing with a few drops of boiling water. It is then laid, together with a colorless bead of microcosmic salt, upon the surface of a piece of charcoal, and heated with the oxidising flame. If cobalt be present, this metal will first oxidise and pass into the microcosmic bead, which must be repeatedly removed and replaced by a colorless bead, until the blue color of the cobalt is no longer perceptible. A perfectly colorless bead of the same salt is then added, and the oxidising flame directed upon the gold bead for the space of about half a minute, to oxidise the nickel. If after this treatment the bead last added has acquired a brownish yellow color, this can only be due to nickel; but if no such color be perceptible, and if the experiment has been conducted with proper precautions, it may be concluded that nickel is absent from the substance.

Lead and Bismuth.—When these two metals are present together in a mineral or alloy, or when either of them is present in so small a proportion that no well-defined or characteristic incrustation is obtainable upon charcoal, the following test is useful. A very small bead of the metal (which, if the substance under examination be a mineral, is obtained by fusing a portion with carbo-

nate of soda upon charcoal), is placed upon a watch glass together with a single drop of strong nitric acid and gently warmed to aid in dissolving it, after which the solution is evaporated nearly, but not quite, to dryness. One or two drops of water are then allowed to flow down upon the residue, and if a trace of bismuth be present, a white precipitate will be formed. If tin or antimony be present, these metals will not dissolve in nitric acid, but will separate out as an insoluble white powder. They may be easily distinguished from one another by their behaviour on charcoal. The presence of lead may be generally known by the malleability of the metallic bead, but as a very small bead of bismuth is likewise tolerably malleable, this character alone is fallacious. It is therefore better in doubtful cases to dissolve another small bead of the metal in nitric acid as above, to add to the solution a single drop of sulphuric acid, and then three or four of strong nitric acid, when, if lead be present, a precipitate will appear. Sulphate of bismuth, on the contrary, will perfectly redissolve and form a clear solution.

Boracic Acid. — *Turner* recommends the following process for the detection of boracic acid in salts and minerals: — The substance is finely powdered and mixed with 1 part of a flux, consisting of $4\frac{1}{2}$ parts of bisulphate of potash and 1 part of finely powdered fluor-spar. A little water is added to the mixture, to form a paste, of which a small portion is placed on a platinum wire and fused in the blue oxidising flame. During the fusion of the mass, fluoboracic acid is formed, which, being driven off, colors the flame siskin-green. This action ceases when the whole of the boracic acid has been eliminated. If the

quantity of the boracic acid present be but small, the outer flame must be carefully observed, as the reaction lasts but a few instants. According to Merlet, 3 or 4 parts of the flux must be added to 1 of the substance under examination in order to obtain certain results.

Silica.—The presence of this acid is best ascertained by fusing a small fragment of the mineral in microcosmic salt. The silica, which is almost insoluble in this salt, separates out and remains suspended in the bead, retaining the form of the original fragment.

Sulphuric Acid and Sulphur.—When sulphur has been detected in any substance by the means described at page 77, in order to determine whether it exists in the form of a sulphide or a sulphate, the following process, described by *Von Kobell*, is to be resorted to. The substance is finely powdered and fused with potash in a platinum spoon, care being taken that the flame impinge on the outer surface only. When cool, the spoon, containing the fused mass, is placed together with a strip of silver foil in a small porcelain vessel containing water slightly acidulated with hydrochloric acid. If the silver foil blackens, a metallic sulphide is present, as in Hauyne, Helvine, etc.; but if it remains bright and untarnished, the presence of a sulphate is indicated. It is evident, that in order to obtain satisfactory results, the substance under examination must be free from any reducing agent, as carbon or organic matter.

Nitric Acid.—When nitrates are heated in a glass-bulb or sealed tube, nitrogen is first evolved, and afterwards nitrous acid, which may be recognised both by its yellow color and its pungent smell. The nitrates of potash and soda deflagrate when heated on charcoal. The presence

of a small quantity of nitric acid may be ascertained by mixing the substance to be tested with rather more than an equal quantity of bisulphate of potash and heating the mixture in a glass-bulb. The color of the nitrous fumes eliminated by this means may be best perceived by looking directly down the neck of the bulb, inasmuch as a thicker stratum of the gas is in this way seen.

Fluorine.—When hydrofluoric acid occurs in small quantity in combination with strong bases and in the presence of a small quantity of water, it is necessary, according to *Berzelius*, to heat the assay in a glass-tube closed at one end, into the open end of which a small strip of Brazil-wood paper has previously been introduced. By this means hydrofluosilicic acid is expelled, which is decomposed, the silica being deposited at a short distance above the assay, and the hydrofluoric acid passing off and coloring the Brazil-wood paper straw yellow. This reaction is obtainable when the substance under examination contains not more than 0,75 % of hydrofluoric acid. If in this experiment neither the siliceous deposit nor the coloration of the Brazil-wood paper be obtained, *Berzelius* recommends the following further experiment. Microcosmic salt, which has been previously fused upon charcoal or platinum, is finely powdered and mixed with some of the substance in question also finely pulverised. A portion of the mixture is introduced into an open glass-tube, and the blowpipe flame so directed upon it, that a part of the flame passes up the tube. By this means, hydrated hydrofluoric acid is formed (if the substance be free from silica), which passes up the tube and may be recognised both by its peculiar pungent smell and by the mode in which it

corrodes the sides of the glass-tube, rendering them dull and opaque wherever any moisture condenses. If Brazil-wood paper be exposed to the action of the gases passing up the tube, it will be colored yellow, affording another indication of the presence of fluorine. If the substance under examination contain silica, fluoride of silicon will be formed, which will be decomposed by the water in the products of combustion, and the silica deposited in solution in the condensed moisture. As the water is evaporated by the increasing heat of the tube, the silica is thrown down on the glass, and is clearly perceptible either with or without the aid of a lens. If now the tube be washed out with water and dried, it will be generally found corroded by the fluorine, which leaves a dull spot wherever it attacks the glass. Moreover if Brazil-wood paper have been introduced during the experiment, it will be found colored yellow. As this experiment requires the application of a strong heat, so that the glass-tube is frequently softened and bent, thus interfering materially with the success of the experiment, *Smithson* has recommended the use of a piece of platinum foil, rolled into a tube and having a portion cut away for about half its length as shown in the figure 9. The tubular end is introduced into the glass-

Fig. 9.



tube, the mixture to be tested for fluorine laid upon the projecting part,

and the flame so directed upon it, that the products of combustion pass up the tube. This arrangement has the advantage that the fused substance does not come in contact with the glass-tube, and the inconveniences attending

the fusing and softening of the glass are altogether avoided. By its aid *Plattner* has obtained most satisfactory results with slags containing mere traces of fluorine.

According to *Merlet*, the following process is also applicable to substances which contain fluorine in any considerable proportion:—The substance previously powdered and mixed with its own weight, or according to *Berzelius* 4 times its weight of fused bisulphate of potash, is strongly heated either with a spirit-lamp or with the blowpipe flame in a glass-tube closed at one end, until sulphuric acid begins to be evolved. The mass should be heated from the top downwards in order to avoid too great frothing up. The upper part of the tube will thus be incrustated more or less with silica deposited from the fluosilicic acid gas which passes off. The lower extremity of the tube, containing the fused mass, is then cut off and the upper part rinsed out with water and dried with blotting paper. If much fluorine be present in the substance operated upon, the glass-tube will be dull all over its inner surface; but if a small quantity only be present, the corrosion will be only partial. This process is less delicate than that above described, viz. with the use of microcosmic salt in the open glass-tube.

Chlorine, Chlorides and Chlorates.—*Berzelius* gives the following method for the detection of chlorine in its compounds. Oxide of copper is dissolved with the oxidising flame in microcosmic salt until a nearly opaque bead is obtained. A small quantity of the substance to be examined is then placed on the fluid bead, and heated in the reducing flame. If chlorine be present, the bead is surrounded with a beautiful blue flame having a tinge of

purple, and this lasts until the whole of the chlorine has been expelled. With an additional quantity of the substance, the reaction may be repeated. With the exception of bromine, no other body affords a similarly colored flame. Another method for the detection of chlorine, also described by *Berzelius*, but which is applicable to soluble chlorides only, is the following.—A small quantity of sulphate of iron* or sulphate of copper is laid upon a piece of polished silver, moistened with water and a small portion of the soluble chloride added. After a few moments a dark bronze-colored stain of chloride of silver is produced upon the surface of the metal. This process is applicable to insoluble chlorides, if they be previously fused with a little carbonate of soda to form chloride of sodium.

Bromine, Bromides and Bromates.—According to *Berzelius*, bromides afford similar reactions to the chlorides, both with the microcosmic salt and oxide of copper, and with sulphate of copper on silver, with the difference that in the former process the flame colored by bromide of copper has no purple tinge, but rather inclines to green, especially at the edges. In order to distinguish with certainty bromides and bromates from their corresponding chlorine compounds, they must be fused with bisulphate of potash in a glass-bulb. By this means sulphurous acid and bromine or chlorine are eliminated, which may be distinguished by their colors and their characteristic un-

* Notwithstanding the high authority on which the use of sulphate (protosulphate) of iron is here recommended, I have been unable to obtain any successful results with that salt. Sulphate of copper answers extremely well, and gives a speedy and characteristic reaction. — [Tr.]

pleasant odors. If bromine be contained in a substance in very small quantity only, it is advisable, immediately after the fusion, to look down the neck of the bulb in order to see the color of a thick stratum of the gas. If chlorine be present, but in small proportion, it is more difficult to detect by this means than bromine, owing to its pale green color. If iodine and bromine be present together, a mixture of yellow bromine fumes with the violet fumes of iodine will be visible.

Iodine, Iodides and Iodates. — According to *Berzelius*, when iodides are treated with microcosmic salt and oxide of copper in the manner described for chlorine compounds, they impart a brilliant green color to the outer flame. If an iodide be fused with bisulphate of potash in a glass-bulb, the iodine is sublimed and partly condensed in the upper part of the neck, the remainder passing off in the form of violet-colored fumes. In order to detect a trace of iodine in the mother liquors obtained in salt-works, a solution of starch, and subsequently chlorine water is added, on the addition of which, an insoluble compound is formed, having a beautiful blue color. *Heine* employs nitric acid instead of chlorine water, and proceeds in the following manner: To the neutral solution supposed to contain iodine, a small quantity of the starch solution is added, and the whole stirred with a glass rod. One or two drops of nitric acid are then added, and the solution again stirred. If iodine be present, even in very small quantity, an intense blue is at once produced.

Magnesia, Tantalic Acid, Alumina, Oxide of Zinc, Oxide of Tin, Oxide of Antimony, Titanic Acid, Niobic Acid, Zirconia. — All these substances when moistened with nitrate

of cobalt and strongly heated, exhibit certain characteristic colors. The powdered substance is mixed into a paste with water, and a portion laid upon charcoal and gently heated. As soon as the water is evaporated, a drop of the cobalt solution is applied to the dry porous mass, by which it is rapidly absorbed. It is then again heated, at first gently, to decompose the nitrate of cobalt, and then strongly with the oxidising flame until the mass is brought to a bright red heat. When allowed to cool, if the substance consist of any of the bodies above enumerated, it will exhibit one of the following colors according to its nature :

Magnesia, flesh tint ; tantalic acid, pink ; alumina, bright blue ; oxide of zinc, fine yellow green (siskin-green) ; oxide of tin, bluish green ; oxide of antimony, dusky green ; titanio acid, yellowish green (less brilliant than oxide of zinc) ; niobic acid, dusky green ; zirconia, dusky violet.

In order to produce these colors it is very essential that the oxide operated upon be pure. The admixture of other oxides produces more or less duskiness and impurity in the colors. The presence of alkalies with silica gives rise to a blue color, due to the formation of a cobalt glass should that metal be present.

Tellurium.—The following method is recommended by *Berzelius* for the detection of small quantities of tellurium. The substance mixed with carbonate of soda and some charcoal is fused in a glass-bulb, and, when cold, a few drops of water previously freed from air by boiling are allowed to fall on the fused mass. After a short time

the water becomes tinged intensely purple by the telluride of sodium which dissolves in it.

Arsenic.—A very small quantity of arsenic in a metallic compound, as, e.g. nickel and cobalt, cannot generally be detected with certainty either in the glass tube or on charcoal. Under these circumstances *Plattner* recommends the following process:—1 part of the finely powdered metal ($\frac{3}{4}$ gr. to 1 gr.) is mixed with from 5 to 6 parts of saltpetre and strongly heated in a platinum spoon. By this means the metals are oxidised, and arseniate of potash is obtained. The fused mass is then boiled in a small quantity of water in a porcelain vessel until all the arseniate is dissolved. The metallic oxides are allowed to subside and the clear solution decanted off into another porcelain vessel. A few drops of sulphuric acid are added, and the solution boiled to expel the nitric acid, after which it is evaporated to dryness. In this operation the sulphuric acid should be added only in sufficient quantity to drive off the nitric acid, or at the utmost to form a bisulphate with the excess of potash. When dry, the salt thus obtained is pulverised in an agate mortar and mixed with about 3 times its volume of oxalate of potash and a little charcoal powder. The mixture is introduced into a glass-bulb having a narrow neck, and gently warmed over a spirit-lamp in order to drive off the moisture, which must be absorbed by a piece of blotting paper in the neck of the bulb. After a short time the temperature is increased to a low red heat, at which the arsenious acid is reduced and the metallic arsenic sublimed, which recondenses in the neck of the bulb, as shown at fig. 10. If then the arsenic be so

small in quantity as to exhibit no metallic lustre, the neck of the bulb may be cut off with a file immediately

Fig. 10.



above the sublimate, and the latter exposed to the flame of the spirit-lamp; the arsenic is then volatilised, and may be recognised by its garlic odor.

The above process is equally applicable to the detection of arseniates and arsenites, the latter part of the process, viz. the heating with oxalate of potash and charcoal, alone being necessary. Equally satisfactory results are obtained with sulphide of arsenic when treated in like manner with 4 or 5 parts of dry oxalate of potash and a small quantity of powdered charcoal: in this case sulphide of potassium is obtained and free arsenic evolved.—According to *Fresenius* and *Babo*, very small quantities of arsenic may be detected by heating the substance to redness in a glass-bulb with 6 parts of a mixture, consisting of equal proportions of cyanide of potassium and dry carbonate of soda.

An important condition for the success of the above processes is that the substance examined for arsenic be perfectly anhydrous before being strongly heated, since the least moisture not only causes the frothing up of the mass, but also oxidises the sublimed arsenic.

The following process is also well adapted to the discovery of small quantities of arsenic. The finely powdered substance is mixed with from 6 to 7 times its volume of saltpetre and fused in a platinum spoon. The fused mass is then treated with boiling water, as above described, and the decanted or filtered solution having

been acidified with acetic acid and boiled, a small crystal of nitrate of silver is added to it. Any arsenic present in the substance will thus have become converted into arsenic acid, and will form an insoluble arseniate of silver easily recognisable by its reddish brown color.

Phosphorus.—Small quantities of phosphorus, which cannot be detected by heating in the platinum forceps, may be found by the following treatment. A mixture is prepared of 3 parts by weight of carbonate of soda, 1 part of saltpetre and 1 of silica. The substance to be examined for phosphorus is then pulverised in an agate mortar, together with 5 times its volume of this mixture, and the whole fused in a platinum spoon. The fused mass is dissolved in water, filtered, to separate the insoluble matter, and to the clear filtrate a few drops of carbonate of ammonia are added. By boiling the solution the silica is separated as a silicate of soda, which is removed by filtration. To this second filtrate, acetic acid is added until the solution is slightly acid; it is then boiled to expel the carbonic acid, and treated with nitrate of silver as in the case of arsenic. A yellow precipitate indicates the presence of phosphorus, which, if it existed previously in the form of a phosphide, has by this treatment been converted into phosphoric acid.

PART II.






THE BEHAVIOUR OF MINERALS BEFORE THE BLOWPIPE.

The examination of minerals with the view of determining their species is one of the principal applications of the blowpipe in the hands of the student, and the ease and celerity with which reliable results are obtained by its aid render this instrument of great importance to all those who, either professionally or otherwise, are interested in the determination of mineral substances. In undertaking such an examination, it must be remembered, that the blowpipe does not enable the student to dispense with a knowledge of the physical characters of minerals, such as their hardness, color, lustre and form of crystallisation, but is rather to be regarded as an auxiliary to such knowledge, enabling him to decide in doubtful cases between two or more species which resemble each other more or less in color and general appearance. Thus Graphite and Molybdenite, minerals which closely resemble each other in their physical characters, may be readily distinguished from one another by holding a small frag-

ment of either mineral in the point of the blue oxidising flame. In the case of Graphite the outer flame will remain uncolored, whereas, if Molybdenite be so treated, a yellowish green streak will be observed in the flame beyond the mineral due to molybdic acid.

Another purpose for which the blowpipe is very useful is that of ascertaining by a simple experiment and with great certainty the presence of certain bodies in a mineral, whether they be essential or non-essential to its composition. Thus the presence of cadmium in zincblende may be readily determined by fusing a small portion of the powdered mineral with carbonate of soda upon charcoal. If cadmium be present, the characteristic orange-colored incrustation of the oxide of that metal will be formed on the charcoal; but if absent, the zinc incrustation alone will be obtained. In like manner a very small trace of manganese may be detected in a mineral by the process described at page 81, and a very minute quantity of arsenic by that described at page 92.

In the following pages the blowpipe characters of the most important and most frequently occurring minerals, tabulated in accordance with the arrangement adopted in the preceding part of this work, are given, to serve either as examples for practice or for the reference of the student in examining undetermined species. The classification of the minerals which is here adopted is that employed by Professor *Dana* in his very excellent handbook, "A Manual of Mineralogy," and which, if not so accurate in a philosophical point of view as that adopted in the recently published edition of his larger work, is far more convenient for practical purposes.



The names of the minerals given in the first column, and which for the sake of brevity are unaccompanied by any synonymes, are those most commonly in use among English mineralogists, and are for the most part those under which the minerals stand described in *Dana's* work. The chemical formulæ of the minerals are given in the second column, and are chiefly on the authority of *Ram-melsberg's* Chemico-Mineralogical Dictionary. With but few exceptions, only the essential constituents of a mineral, or those which, being non-essential, are almost constantly present, are mentioned either in its chemical formula or in the other columns of the table, as affecting its blowpipe reactions. The principal impurities and incidental constituents (with the above exceptions) are mentioned in the notes at the end of each table, and where several minerals occur having a nearly similar composition as regards the nature of their elements, only the most important of these are described at length in the tables, and the others, if not of very rare occurrence, are briefly enumerated at the end. The remaining columns are constructed with reference to the eight sections into which the former part of this work is divided, and, where practicable, the student is referred back to these for a description of the phenomena presented by the various oxides and simple bodies in the processes of investigation.

In the case of the mineral resins and organic minerals, such as coal, jet, amber, etc., the plan of investigation is somewhat modified. Since carbon, hydrogen and oxygen, the elements which chiefly enter into the composition of these minerals, afford no characteristic reactions in borax, or microcosmic salt or with carbonate of soda, these tests

are omitted, and the only processes to which it is necessary to subject such minerals are heating them, 1st, without, and 2nd, with access of air, the former in a glass-bulb or tube sealed at one end, the latter either on charcoal or platinum foil. Many of these minerals, when all combustible matter has been consumed, leave a larger or smaller quantity of ash, which may, if requisite, be separately examined in the same manner as an inorganic mineral; but as such an examination would fail to afford any useful indications as to the nature of the mineral, it is not here included.

Again, in the case of the alkaline and earthy silicates, owing to the great similarity of many of these minerals in their ultimate composition, a detailed description of the blowpipe characters of each mineral would in most cases consist in a mere verbal repetition, indicating but little by which any particular mineral might be characterised. The blowpipe characters most useful in examining this very numerous class of minerals are, 1st, their fusibility, 2nd, their behaviour with carbonate of soda, and 3rd, their behaviour in the glass-bulb as indicating a hydrous or anhydrous composition. According to these three characters, the principal silicates will therefore be tabulated, and such only as afford certain characteristic reactions will be selected for a somewhat more detailed description.

CARBON AND ORGANIC MINERALS.

(Behaviour in glass-bulb, see page 102.)

Under the head of carbon minerals are here included not only those minerals which, as the diamond, graphite, etc., consist of carbon and its inorganic compounds, but also those combinations of carbon with hydrogen, oxygen, etc., the investigation of which falls within the province of organic chemistry. The minerals included in this last section are characterised by their affording an empyreumatic odor when heated in the glass-bulb, frequently accompanied by the elimination of tar, naphtha and other volatile hydro-carbons, which are partly condensed in the neck of the bulb. When heated with the blowpipe flame upon platinum foil, they mostly take fire and burn with a bright yellow flame, whereas the diamond, graphite and anthracite, which consist of little else than pure carbon, are gradually consumed, accompanied at most by a pale blue flame.

Mineral.	Formula.	Behaviour	
		in glass-bulb.	on platinum foil.
Diamond - -	C	—	In fine powder is slowly consumed without residue in a strong oxidising flame.
Graphite - -	C with some iron, silica, etc.	Generally gives off water.	Is slowly consumed leaving more or less ash, principally Fe_2O_3 .
Anthracite -	$\text{C} + x\text{H}$ and some ash.	Evolves water.	Is slowly consumed with the exception of a small quantity of ash.
Wallsend-coal-	C, H, N, O, S, and ash.	Intumesces and gives off water and tarry matters which partly condense in bulb, and leave a porous coke.	Takes fire under blowpipe flame, and burns with a smoky flame depositing much soot, and leaving a porous cinder, which burns slowly, and leaves a small ash.
Cannel-coal -	C, H, N, O, S, and ash.	As the preceding, but gives off more tar.	Similar to the preceding. If held to the lamp-flame, takes fire and burns for some seconds.
Brown-coal -	C, H, N, O, S, and ash.	Gives off much water and tar, and leaves a porous cinder retaining the form of the original fragment.	Burns slowly and without flame, leaving some ash.
Asphaltum -	$\text{C} + \text{H} + \text{O}$.	Fuses with ease, affording an em-	Takes fire and burns with a

Mineral.	Formula.	Behaviour	
		in glass-bulb.	on platinum foil.
Asphaltum - (Continuation of p. 102)	$C + H + O.$	pyreumatic oil having an alkaline reaction, and combustible gases, and leaves a carbonaceous residue, which is entirely consumed under the blowpipe flame, except a small ash.	bright flame and a thick smoke.
Elastrite - -	$C + H.$	Fuses and gives off water having an acid reaction, naphtha and a tarry fluid, which chiefly condense in the neck of the bulb and leave a light, pulverulent carbonaceous residue.	Fuses, takes fire and burns with a smoky flame, leaving a carbonaceous residue, which under the blowpipe flame is quickly consumed with the exception of an ash.
Hachettine -	$C_n H_n$	Fuses to a clear colorless liquid, which solidifies on cooling and has a tallow-like smell.	Fuses, takes fire and burns with a bright flame until entirely consumed.
Ozokerite - -	$C + H.$	Fuses readily to a clear brown oily fluid, which solidifies on cooling.	As the preceding.
Amber - - -	$C_{40} H_{64} O_4$	Fuses with difficulty and affords water, an empyreumatic oil, and succinic acid, which condense in the neck of the	Takes fire and burns with a yellow flame and a peculiar aromatic odor.

Mineral.	Formula.	Behaviour	
		in glass-tube.	on platinum foil.
Amber - - - (Continuation of p. 103).	$C_{40} H_{64} O_4$	bulb, leaving a shining black re- sidue.	(See p. 103.)
Mellite- - -	$Al_2 O_3 \overline{M}_3$ $+ 18 H_2 O.$	Gives off water. If heated to redness is carbonised and gives a slight em- pyreumatic odor.	On charcoal burns to a white ash, which moistened with nitrate of cobalt and heated shows the alumina reaction.

The minerals above enumerated, although among the most important of the organic class, are but a few of the numerous species which have been described by various authors. Many of these, however, are of extremely rare occurrence, and are not of sufficient interest to demand notice in this place. With regard to the varieties of coal, four only are here enumerated, viz.: Anthracite, cannel-coal, Wallsend- (bituminous) coal and brown-coal. These may be regarded as four typical varieties, between which there are coals of all gradations of character, as cherry-coal, splint-coal, etc., and an infinite variety of coals, which have received local names, an enumeration of which would be here out of place.

S U L P H U R.

(Behaviour in glass-bulb see p. 21, in the open tube p. 23, with carbonate of soda p. 77.)

Native sulphur is easily recognised by its fusing, volatilising with little or no residue, and recondensing when heated in the glass-bulb; by its burning with a blue flame, and with the formation of sulphurous acid when strongly heated in the open tube; and by its producing a black stain upon silver when having been fused with carbonate of soda on charcoal, the fused mass is placed upon a piece of polished silver and moistened with one or two drops of water.

For the notice of the metallic sulphides and sulphates see the various metals.

P O T A S H.

(Behaviour in forceps or on platinum wire see p. 33. Mode of detection of potash in the presence of soda see p. 78.)

If we exclude from consideration those compounds in which potash is present in greater or small quantity, the minerals of this alkali are few in number and with one exception, viz. nitre, of no great importance.

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	
Nitre - - -	KNO_3	Fuses readily to a clear liquid, and with a strong heat boils with the evolution of oxygen.	—	Dissolves in water so that a glass plate can be placed over it.
Polyhalite- -	$2\text{R}\text{SO}_4 + \text{Aq}$ $\text{R} = \frac{1}{2}\text{K}_2$ $+ \frac{1}{2}\text{Ca} + \frac{1}{2}\text{Mg}$	Gives off water.	—	Fuses with effervescence so that it can be shown to be a salt.

Nitre is rarely found pure. It generally contains more or less chloride of potassium and sulphate of potash.

The violet color imparted by potash to the blowpipe flame is very characteristic, and is a very certain test, if soda be absent. If, however, besides potash, soda be present in a mineral, recourse must be had to the process described at p. 78 for the detection of the former alkali. With the exception of the silicates, all the potash minerals are soluble in water, and may generally be distinguished by their taste when applied to the tongue.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
platinum fuses and the violet or less by and soda.	—	—	—	With bisulphate of potash in the glass-bulb evolves nitrous fumes (see p. 85).
platinum fuses and the yellow a small quantity of soda.	Dissolves with ebullition to a clear glass, which is slightly colored by iron, and when saturated becomes opaque on cooling.	As in borax.	Fuses. The alkalies are absorbed by the charcoal, leaving the lime and magnesia infusible on the surface.	The alkaline mass when laid on silver gives a sulphur reaction.

occasionally salts of soda, lime and magnesia. — For *Alunite and native alum* see alumina.

S O D A.

(Behaviour in forceps or on platinum wire see p. 32.)

The intense orange-yellow color, which all soda-salts impart to the blowpipe flame, is in all cases a sufficient

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal.
Rock-salt - -	NaCl.	Fuses to a clear liquid.	—	Fuses, sorbed charcoal partially fused, giving the coal a
Natron- - -	Na ₂ CO ₃ + 10 Aq.	Fuses with the evolution of water.	—	Fuses absorb the phosphorus of the charcoal
Soda-nitre- -	NaNO ₃	Fuses and if strongly heated evolves nitrous fumes.	—	Deflagrates and absorbs charcoal
Glauber-salt -	Na ₂ SO ₄ + 10 Aq.	Fuses and gives off water having a neutral reaction.	—	Fuses absorb the charcoal. The sugar charcoal upon gives a phosphorus

indication of the presence of this alkali. With the exception of Cryolite, all the minerals mentioned in the following table are soluble, and many of them may be recognised by their characteristic taste; especially rock-salt and soda-nitre.

eps.	Behaviour			(8) Special reactions.
	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
with e and the allow.	—	—	—	Gives the chlorine re- actions (see p. 88).
d be- ; the ing.	—	—	—	Dissolves in acids with violent effe- rescence.
ates inum oring ame w.	—	—	—	In a glass-bulb with bisul- phate of pot- ash, gives the NO ₂ -reaction (see p. 85).
d co- flame v.	—	—	—	Gives the SO ₃ -reaction (see p. 85).

S O D A. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on
Glauberite - -	Na_2SO_4 + CaSO_4 .	Decrepitates with the evolution of more or less water, and when strongly heated fuses to a clear liquid.	—	Fuse clear then out; is a and left face. silver mass sulph
Borax - - -	NaBO_2 + HBO_2 + 5 Aq.	Intumesces with the evolution of water, and under a strong heat fuses.	—	Intumesces clear more color in
Cryolite - -	$\text{Na}_6\text{Al}_2\text{F}_{12}$.	Decrepitates slightly and gives a trace of water.	If heated, so that the flame be allowed to play up the tube upon the mineral, fluorine is evolved, which corrodes the interior of the tube.	Fuse pidb on come enan hea some bubbl off and in

Most of the above minerals are rarely found pure and those to the composition of which sulphate of soda and chloride of sodium are non-essential, frequently contain more or less of these salts as impurities, together

f pages 108 and 109.)

Behaviour				(8) Special reactions.
(1) Reps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
easily clear color-flame w.	Fuses easily and gives the lime reaction.	As in borax.	As alone on charcoal.	Gives the SO_3 -reaction (see p. 85).
char-	—	—	Fuses to a clear bead, which becomes crystalline on cooling.	Gives the boracic-acid-reaction. (see p. 84).
color-flame w.	Dissolves to a clear bead which is rendered opaque by a large addition.	As in borax.	Fuses to a clear bead, then spreads out on the charcoal, the soda is absorbed, and an infusible mass of alumina remains.	If the alumina residue obtained be moistened with cobalt solution and heated strongly, it assumes a beautiful blue color.

with more or less magnesia, lime or iron. These, if present in any quantity, can be easily detected by resorting to the proper tests as given elsewhere.

BARYTA AND STRONTIA.

Baryta (behaviour in platinum forceps see p. 36, in borax and microcosmic salt Table I., with carbonate of soda p. 75).—The principal blowpipe characters of baryta minerals are: the green color they impart to the blowpipe flame, which distinguishes them from strontia and lime minerals, and their property, when fused upon charcoal with carbonate of soda, of being absorbed into the pores of the charcoal, by which baryta is distinguished from all the earths, excepting strontia. A borax bead con-

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Heavy-spar -	Ba SO ₄	Sometimes decrepitates and gives off more or less water.	—	Fuses in reducing flame
Celestine - -	Sr SO ₄	—	—	Fuses to milk-white bead

taining baryta and rendered opaque by an intermittent flame, has a milk-white appearance, whereas lime, magnesia and alumina, under the same circumstances, afford a crystalline bead.

Strontia (behaviour in platinum forceps see p. 35, in borax and microcosmic salt Table I., with carbonate of soda p. 75). Strontia minerals resemble those of baryta in their reactions in the borax bead, and with carbonate of soda upon charcoal. They are distinguished from the latter by the color they impart to the blowpipe flame.

Behaviour				(8)
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	Special reactions.
es with salty on a. Colors ater flame a. In the wing flame as Ba S, ch fuses readily.	Gives the baryta-reac- tion.	As in borax.	Fuses to a clear bead; then spreads out and is ab- sorbed into the charcoal. The fused mass laid on silver gives the S-reac- tion.	If fused with potash on pla- tinum gives the SO ₃ -reaction (see p. 85).
II. ders the the crim- son.	Gives the strontia-reac- tion.	As in borax.	Similar to the preceding.	Similar to the preceding.

BARYTA AND STRONTIAN

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on heating
Witherite -	BaCO_3	Decrepitates more or less and evolves water.	—	Fuse vesic. partly sorbed on heating
Strontianite -	SrCO_3	Becomes opaque.	—	As in case of baryta
Barytocalcite -	$\text{BaCO}_3 + \text{CaCO}_3$	As the preceding.	—	In frit but not fused

The above minerals frequently contain more or less iron, magnesia and lime as impurities. Heavy-spar also occasionally contains strontia in small quantity, but as the *baryta* is in large excess, the green color produced by this

tinuation of pages 112 and 113.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
I. In the flame in- ly green.	Dissolves with effervescence and gives the baryta - reac- tion.	As in borax.	Fuses to a clear bead; then spreads out and passes into the char- coal.	In dilute HCl dissolves with much efferves- cence.
Fluorides and oxides of barium. The beads glow intensely and on the beads. Colors are brill- y crim- son.	Resembles the preceding.	As in borax.	As the pre- ceding.	As the pre- ceding.
IV. In the green the centre red to- ls the joint.	Dissolves with effervescence. In large quan- tity gives a semi - crystal- line bead.	As in borax, but the satu- rated bead is milk-white.	Fuses, and is partially ab- sorbed, leaving the lime on the surface.	As witherite.

earth in the blowpipe flame overpowers that produced by the strontia, and the latter can therefore only be detected by a wet analysis.

L I M E.

(Behaviour in the forceps see p. 35, in borax and microcosmic salt Table I., with carbonate of soda p. 75.)

Most lime minerals, except the silicates and those containing soda or baryta, may be recognised by the red color they impart to the blowpipe flame, and their behaviour in the borax and microcosmic beads, and on charcoal with carbonate of soda. These characters distinguish

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Gypsum - -	$\text{Ca SO}_4 + 2 \text{ Aq.}$	Turns white, giving off water and being converted into plaster of Paris.	—	In the reducing forms which become alkaline on paper, gives a phosphuretted hydrogen when heated in silver moist
Apatite - -	$\text{Ca} \left\{ \begin{array}{l} \text{Cl}_2 \\ \text{F}_2 \end{array} + 3 \right. \\ (\text{Ca}_3 2 \text{ PO}_4)$	Occasionally decrepitates and gives off some water.	—	—

lime from baryta and strontia, while its negative character of assuming no distinctive color, when treated with nitrate of cobalt, distinguishes it from alumina and magnesia. If, however, magnesia, alumina, iron or manganese be present in any considerable quantity, recourse must be had to an analysis by the wet way to establish the presence of lime. When by this means the alkaline earths have been separated from one another, they may be tested under the blowpipe in the usual manner.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
es with alty to a coloring flame red.	Dissolves to a clear bead, which gives the lime-reac- tion.	As in borax.	Behaves as lime. The alkaline mass laid on silver and moistened gives the sul- phur-reaction.	Gives the sulphuric acid-reaction.
IV. viciously ed in SO ₂ ors the e green, wards red.	Dissolves easily and when in some quantity gives an opaline bead.	Gives the lime-reaction.	Is infusible. The alkali is absorbed, leav- ing the lime on the surface of the char- coal.	With micro- cosmic salt and oxide of cop- per gives the chlorine-reac- tion (p. 88). With micro- cosmic salt in the open tube evolves fluo- rine (p. 86).

LIME. (Ca)

Mineral.	Formula.	Behaviour	
		(1) in glass-bulb.	(2) in open tube.
Pharmacolite	$\text{Ca}_2 2 \text{AsO}_4$ + $\text{H}_3 \text{AsO}_4$ + 5Aq.	Gives off water, and emits an arsenical odor.	—
Calcspars - -	CaCO_3	Turns white and sometimes decrepitates. Strongly heated loses CO_2 and becomes caustic.	—
Fluorspar - -	CaF_2	Phosphoresces with various colors when heated in the dark. Sometimes decrepitates and gives a trace of water. Becomes opalescent.	—

Most of the above minerals contain occasionally magnesia and manganese as impurities in variable portions. Calcspars especially may contain a large centage of these oxides, passing gradually into Dolomite on the one hand, and into Siderite and Diallogite on the other. Fluorspar contains occasionally minute quantities of phosphoric acid and chlorine.

Among the more important minerals of lime is *Anhydrite* (CaSO_4), which behaves in all respects like *gypsum*, except that being anhydrous it evolves little

pages 116 and 117.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
uses to a is lucent t-colored , the color g due to lt. Colors lame blue rst, then itly red.	Dissolves readily to a bead strongly colored by cobalt, which obscures the lime-reaction.	As in borax.	Fuses and emits As. The alkali is then absorbed by the char- coal as in the preceding.	—
V. rs bril- ly, color- the flame Becomes sic and ows a ug alka- reaction.	Dissolves with evolution of CO ₂ and when pure gives the lime-reaction. The bead is generally more or less colored by iron and manganese.	As in borax.	Fuses and be- haves as other lime-salts.	Dissolves with effervescence in cold HCl.
on char- Colors flame red.	Gives the lime-reaction.	As in borax.	Fuses to a clear bead, opaque on cooling. With an addition of the alkali be- haves as lime.	With micro- cosmic salt in open tube gives the fluo- rine reaction (p. 86).

no water in the glass-bulb; Arragonite, which behaves as calcspar, and sometimes gives indications of strontia and lead (Plumbocalcite), and Dolomite or Bitterspar ($\text{Ca CO}_3 + x\text{Mg CO}_3$), which differs from calcspar in being insoluble in cold hydrochloric acid but soluble in warm acid.

For the blowpipe characters of Polyhalite see potash; for Glauberite, soda; for Barytocalcite, baryta; and for Scheelite, tungsten. For Wollastonite, Datholite, etc. see the *silicates*.

MAGNESIA.

(Behaviour in borax and microcosmic salt see Table I. With cobalt solution p. 91.)

The most distinctive reaction of magnesia is the flesh-tint which it assumes when moistened with nitrate of cobalt and strongly heated upon charcoal. When, on account of the presence of metallic oxides, this test becomes inapplicable, in order to establish the presence of magnesia,

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Brucite - -	$\text{Mg H}_2 \text{O}_2$	Evolves water.	—	—
Epsomite - -	$\text{MgSO}_4 + 7 \text{Aq.}$	Evolves water, having an acid reaction on test paper.	—	Gives off and S shines liantly ar comes all and cau
Boracite - -	$\text{Mg}_3 \text{B}_3 \text{O}_{15}$	Occasionally gives off a trace of water.	—	Fuses intumes to a crystal bead

recourse must be had to a wet analysis, since the negative character (which it possesses in common with alumina and the rarer earths, glucina, yttria, etc.) of imparting no color to the blowpipe-flame, is scarcely sufficiently indicative; and its behaviour in borax and microcosmic salt, and with carbonate of soda on charcoal, exactly resembles that of lime. The principal magnesian minerals are however easy to recognise by their physical characters, and on these the student must principally rely.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V.	Behaves as magnesia. Sometimes gives a faint iron-reaction.	As in borax.	Behaves as magnesia (see above).	With nitrate of cobalt gives the magnesia-reaction.
V. on charcoal.	Behaves as magnesia.	As in borax.	The alkali is absorbed, leaving the magnesia on the surface of the charcoal. Gives the sulphur-reaction on silver.	The magnesian residue obtained on treating with carbonate of soda (7) assumes a flesh-tint when treated with cobalt.
I. on charcoal. Colors flame green.	Fuses easily to a clear bead which is crystalline when containing much of the mineral, and is usually slightly tinted by iron.	As in borax.	With a small quantity of alkali fuses to a clear bead crystalline on cooling. With a larger quantity gives a clear uncrySTALLISABLE bead.	

MAGNESIA. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Magnesite	MgCO_3	Sometimes gives off a small quantity of water.	—	Is infusible. With solution assumes a flesh tinge.
Mesitine spar	$(\text{MgFeMn})\text{CO}_3$	As magnesite.	—	Is infusible. Assumes deep blue color.

The magnesian minerals above enumerated frequently contain small quantities of lime, iron and manganese, of which the two latter may be detected by the color they impart to the borax bead. Brucite also occasionally contains a small quantity of carbonic acid and magnesite of sulphuric acid.

Other magnesian minerals of less importance are Periclase (MgO), which behaves as Brucite, except that in the glass-bulb no water is evolved; Hydromagnesite,

ages 120 and 121.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V.	Behaves as magnesia. Sometimes gives a slight iron-reaction.	As in borax.	Fuses to a bead, the soda is then absorbed, leaving an infusible mass of magnesia.	The magnesian residue obtained by fusing with carbonate of soda gives the magnesian-reaction with nitrate of cobalt. — Dissolves with effervescence in warm H Cl.
V.	Gives the iron- and manganese reaction.	As in borax.	As magnesite, but the residual mass has a dark color from iron and manganese.	Dissolves with effervescence in warm H Cl. With carbonate of soda and nitre gives a manganese-reaction.

which resembles Magnesite in its reactions, but gives off a considerable quantity of water in the glass-bulb; Wagnerite ($\text{Mg}_3 2\text{PO}_4 + \text{MgF}_2$), which is characterised by imparting a green color to the blowpipe-flame when moistened with sulphuric acid, and by corroding the glass-tube when fused with microcosmic salt as described at page 86.

For Dolomite see lime, for Polyhalite see potash, for Spinel and Lazulite see alumina.

A L U M I N A.

(Behaviour in borax and microcosmic salt see Table I. With cobalt solution p. 91.)

Under the blowpipe-flame, alumina is distinguished from the other earths by its property of assuming a beautiful blue color, when moistened with nitrate of co-

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Sapphire Corundum Emery	Al_2O_3	—	—	—
Websterite	$Al_2SO_4 + 9 Aq$	Gives off water, and, when heated to incipient redness, sulphurous acid.	—	Gives off ter and leaving as fusible n
Native Alum	$R SO_4 + Al_2 3SO_4 + 24 Aq.$	Intumesces greatly and gives off much water. Strongly heated evolves SO^3 , which reddens litmus.	—	Intumes and bec infusibl

balt and strongly heated upon charcoal. As in the case of magnesia, this test becomes inapplicable when colored metallic oxides, as those of iron, manganese, etc., are present, in which case recourse must be had to the wet way to distinguish alumina from those earths which, like it, impart no color to the blowpipe-flame.

Behaviour				(8) Special reactions.
(4) recepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V.	In fine powder dissolves slowly to a colorless glass.	As in borax.	—	In fine powder moistened with cobalt-solution and heated assumes a blue color.
V.	Behaves as alumina.	As in borax.	Yields an infusible mass, which laid on silver and moistened produces a black stain.	Fused with potash in platinum has no action on silver (p. 85). Cobalt-solution produces the alumina-reaction.
V. ors the e violet a potash l, yellow soda be resent.	Dissolves and gives the iron- and manganese-reaction, if these oxides be present. Otherwise the bead is colorless.	As in borax.	The alkali is absorbed into the charcoal, leaving an infusible mass, which gives the sulphur-reaction on silver.	If not containing much iron or manganese, gives an alumina-reaction with nitrate of cobalt. In other respects as the preceding.

ALUMINA. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Turquoise -	$\text{Al}_2 \text{P}_2 \text{O}_{11}$ + 5 Aq.	Evolves water, occasionally decrepitates and turns black.	—	Turns br but rem infusibl
Wavellite -	$\text{Al}_2 2 \text{PO}_4$ + $\text{Al H}_3 \text{O}_3$ + 5 Aq.	Evolves water and some fluorine, which attacks the glass.	—	Exfoliate turns wh
Spinel - - -	$\text{R}'' \text{Al}_2 \text{O}_4$	—	—	—

Of the above-mentioned minerals, two, viz. native Alum and Spinel, are exceedingly variable in their composition. In the former the element R may be represented by one or more of the following isomorphous bases, viz. potash, soda, ammonia, magnesia, protoxide of manganese and protoxide of iron, which may be present in any

ages 124 and 125.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V. on char- Colors outer e green.	In the oxidising flame gives a green bead, due to copper and iron. In reducing flame opaque-red.	As in borax.	Intumesces; then fuses to a semi-clear glass colored by iron. With more alkali yields an infusible mass.	Gives the phosphoric-acid reaction (p. 94).
V. on char- Colors outer e green, sially if tened with SO ₂ .	As alumina. Generally gives also a slight iron-reaction.	As in borax.	Forms an infusible white mass.	With cobalt-solution on charcoal gives the alumina-reaction.
V.	Gives a slight iron-reaction.	As in borax.	Fuses partially and forms a porous mass.	With nitrate of cobalt gives the alumina-reaction. With nitre and carbonate of soda a slight manganese-reaction.

relative proportions. The most common and best known of the varieties of alum is potash-alum, but this, in the native state, always contains more or less iron and generally some soda. The general behaviour of the alum before the blowpipe is that given in the table with certain modifications according to the presence or absence of the

various bases just enumerated. In Spinel, in the same manner, R, although generally consisting principally of magnesia, may be represented to any extent by other bases, e.g. by zinc in the variety Automolite, by iron in Hercinite, and by lime, manganese and copper in smaller proportions. In Automolite the presence of zinc is easily recognised by its affording a white incrustation of the oxide of that metal, when fused with carbonate of soda upon charcoal (see p. 27). The oxide of copper in the variety Chlorospinel is also readily detected by its characteristic reaction in microcosmic salt.

Besides the minerals just enumerated the following are important: Diaspore ($H_2 Al_2 O_4$), which behaves as corundum, but gives off a considerable quantity of water, when heated in the glass-tube; Alunite ($K_2 SO_4 + Al_2 3 SO_4 + 2 Al_2 H_6 O_6$), which in the glass-bulb decrepitates, and gives off water and sulphate of ammonia; on charcoal shrinks up, but does not fuse, and in microcosmic salt leaves a siliceous skeleton, but behaves in other respects similar to alum; Lazulite ($Al_2 2 PO_4 + R^{\sim} H_2 O_2$), being represented by magnesia, lime and iron, which in the glass-bulb gives off water and loses color, on charcoal intumescs, but does not fuse, in the forceps colors the flame green, and moistened with cobalt-solution gives the alumina-reaction; Childrenite, a phosphate of iron, manganese and alumina, which in the glass-bulb gives off water, in borax and microcosmic salt gives the iron- and manganese-reactions, and in the forceps froths up, colors the outer flame bluish-green, and is somewhat fused on the edges.

For Cryolite see soda.

S I L I C A.

(Behaviour in borax and microcosmic salt see Table I. In carbonate of soda p. 75.)

Silica minerals, i.e. minerals consisting entirely or almost entirely of silica, are readily distinguished for the most part by their mineralogical characters. They are divided into two species, the hydrous and the anhydrous, the former comprising the different varieties of opal, as : precious-opal, common-opal, semi-opal, wood-opal, *Müller's* glass or Hyalite, and the earthy varieties Cacholong and siliceous sinter ; and the latter the varieties of Quartz, as : Rock crystal, Amethyst, Prase, Cat's-eye, Aventurine, Hornstone, Jasper, Chalcedony and Chrysoprase. The varieties of silica are characterised under the blowpipe by their infusibility, their insolubility in microcosmic salt, and by fusing with carbonate of soda to a clear glass, which remains transparent on cooling. The hydrous varieties are distinguished from the anhydrous by giving off water, when heated to redness in a tube sealed at one end. In borax the pure varieties dissolve slowly to a clear glass ; the impure also dissolve and color the borax generally more or less strongly with iron or some other metallic oxide. Alumina and lime are also frequently present in minute proportions, and may be detected by the wet way. Nickel is present in the green anhydrous variety Chlorophane.

SILICATES.

(Behaviour in forceps see page 42, with carbonate of soda page 76.)

The large and important group of minerals which consist essentially of silica in combination with the earthy bases, lime, magnesia and alumina, are with a few exceptions those which afford the least satisfactory results under the blowpipe. Since a very large number of them differ from one another, not in the nature, but solely in the relative proportions of their components, either a quantitative analysis or a thorough knowledge of their physical characters is necessary to enable the student to draw any certain conclusions as to species; and a blowpipe examination can do little more than, by affording a knowledge of the fusibility of a mineral silicate, of its behaviour with carbonate of soda, and of the presence or absence of water, place it by the side of some twenty others which more or less resemble it in these characters, and from which it is to be distinguished only by analysis or by its physical characters. Some few silicates contain more or less fluorine, chlorine, or boracic acid, and with regard to these more definite conclusions may be frequently arrived at by means of the blowpipe. Lithia and chromium, which also occur in comparatively but few silicates, are likewise characteristic. But the rare earthy bases, zirconia, yttria, glucina, etc., afford no distinctive reactions under the blowpipe, and a wet analysis is requisite in order to detect their presence. Iron and manganese occur frequently in the earthy silicates replacing lime, mag-

nesia and alumina, or as essential constituents, so that from their presence no definite conclusions can be drawn as to species.

The presence of silica in a mineral can easily be ascertained by treating a small fragment in a bead of microcosmic salt. The bases will dissolve out with more or less difficulty in the salt, and the silica being insoluble will remain suspended in the bead, retaining the original form of the fragment. In borax the silicates of lime and magnesia generally dissolve with considerable ease, but those of alumina slowly and with difficulty. The silicates of lime are moreover frequently characterized by intumescence or ebullition, when heated in the forceps in the blowpipe flame. The minerals presenting this character are marked in the table. As the most convenient mode of classifying the silicates for blowpipe examination, the following arrangement will be adopted :—

I. Anhydrous Silicates.

II. Hydrous Silicates. Fusibility I. to V.

- a. Afford a fluid bead with carbonate of soda.
- b. Afford a fluid bead with but little of that salt,
but with a larger quantity a slaggy mass.
- c. Afford a slaggy mass only.

This classification of minerals according to their fusibility and their behaviour with carbonate of soda was originally proposed by *Berzelius*, and a table of the principal oxidised minerals arranged according to these characters is given in his handbook of the blowpipe, and thence adopted with some alterations by *Plattner* in the very excellent and detailed work already many times cited. In

the following general table I. the more important silicat only are included, and in table II. are enumerated in alphabetical order those which afford characteristic reactions.

TABLE I.
A n h y d r o u s .

Fus. alone and with Na ₂ CO ₃ .	Mineral.	Formula.
I. a.	Axinite - - - - -	$6 (\text{Ca Mg})_2 \text{SiO}_4 + 4 (\text{Al, Mn Fe})_4 3 \text{SiO}_4 + \text{B}_4 3 \text{SiO}_4$
	Elæolite - - - - -	$2 (\text{K}_2 \text{Na}_2)_2 \text{SiO}_4 + 2 \text{Al}_4 3 \text{SiO}_4 + \text{SiO}_2$
	Garnet - - - - -	$3 (\text{Fe, Mn, Mg, Ca})_2 \text{SiO}_4 + (\text{Al, Fe})_4 3 \text{SiO}_4$
	Oligoclase - - - - -	$(\text{Ca, Na}_2)_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4 + 5 \text{SiO}_2$
	Scapolite - - - - -	$3 (\text{Ca, Na}_2)_2 \text{SiO}_4 + 2 \text{Al}_4 3 \text{SiO}_4 + 3 \text{SiO}_2$
	Spodumene - - - - -	$3 (\text{Li}_2 \text{Na}_2 \text{Ca}) \text{SiO}_3 + 4 (\text{Al}_2 3 \text{SiO}_3)$
b.	Asbestos to II. - - -	as Hornblende
	Augite - - - - -	$(\text{Ca, Mg, Fe, Mn}) \text{SiO}_3$
	Epidote - - - - -	$3 \text{Ca}_2 \text{SiO}_4 + 2 (\text{Al}_4 3 \text{SiO}_4)$
	Hornblende - - - - -	$(\text{Mg, Ca, Fe, Mn}) \text{SiO}_3$ with some alumina replacing SiO
	Sodalite - - - - -	$3 (\text{Na}_4 \text{SiO}_4) + 3 (\text{Al}_4 3 \text{SiO}_4) + 2 \text{Na Cl}$
	Vesuvian - - - - -	$9 (\text{Ca, Fe})_2 \text{SiO}_4 + 2 (\text{Al}_4 3 \text{SiO}_4)$
c.	Biaxial Mica - - - - -	$(\text{K}_2 \text{Mg}) \text{SiO}_4 + (\text{Al, Fe})_4 3 \text{SiO}_4 + \text{SiO}_2$

one th 3.	Mineral.	Formula.	
.	Haüyne - - - -	$3 [\text{Na}_4 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4] + 4 \text{CaSO}_4$	
	Tourmaline to V. - -	$(\text{Mg}_3, \text{Ca}_3, \text{Fe}_3, \text{Mn}_3, \text{K}_6, \text{Na}_6, \text{Fe}_2, \text{Al}_2, \text{B}_2)_6 \text{O}_6 9 \text{Si} (\text{OF}_2)_4$	Int.
1.	Labradorite - - - -	$(\text{Ca}, \text{Na}_2)_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4 + 2 \text{SiO}_2$	
	Lepidolite - - - -	$2 [(\text{K}_6 \text{Li}_3 \text{Mn}_2 \text{Al}_2)_2 3 \text{SiO}_4] + 3 \text{SiO}_2$	
	Rhyacolite - - - -	$\text{K}_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4 + 8 \text{SiO}_2$	
.	Augite - - - -	See above	
	Actinolite - - - -	See Hornblende	Int.
	Diopside - - - -	See Augite	
	Humboldtite - - - -	$6 (\text{Ca}, \text{Mg}, \text{Na}_2)_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4$	
	Sahlite - - - -	See Augite	
	Tremolite - - - -	As Hornblende without alumina	Int.
.	Pyrope - - - -	$3 (\text{Mg} \text{Ca} \text{Fe})_2 \text{SiO}_4 + (\text{Al}, \text{Cr})_4 3 \text{SiO}_4$	
1.	Anorthite - - - -	$\text{Ca}_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4$	
	Nepheline - - - -	See Elæolite	
	Obsidian - - - -	Indefinite, $\text{SiO}_2, \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3, \text{FeO}, \text{CaO}, \text{Na}_2\text{O}, \text{K}_2\text{O}$	Int.
	Orthoclase - - - -	As Rhyacolite	
	Petalite - - - -	$3 (\text{Li}_2 \text{Na}_2)_2 \text{SiO}_4 + 4 \text{Al}_4 3 \text{SiO}_4 + 6 \text{SiO}_2$	

Fus. alone and with Na ₂ CO ₃ .	Mineral.	Formula.
III. a.	Pumice - - - - -	Indefinite, SiO ₂ , Al ₂ O ₃ , 1 CaO, Na ₂ O, K ₂ O, H ₂ O
b.	Gadolinite to V. - -	Apparently variable, SiO ₂ , CeO, FeO, BeO
	Nephrite - - - - -	As Hornblende, with little alumina
	Wollastonite - - - -	Ca SiO ₃
c.	Iolite - - - - -	(Mg, Fe) ₂ SiO ₄ + Al ₄ : + 2 SiO ₂
IV. a.	Beryl - - - - -	3 Be SiO ₃ + Al ₂ 3 SiO ₃
b.	Diallage - - - - -	As Hornblende, with Al ₂
	Hypersthene - - - -	(Mg, Fe) SiO ₃
c.	Fuchsite - - - - -	As Muscovite, containing
V. a.	Leucite - - - - -	K ₄ SiO ₄ + Al ₄ 3 SiO ₄ + 4
b.	Chondrodite - - - -	Mg ₃ O ₂ 3 Si(OF ₂) ₄
	Olivine - - - - -	(Mg, Fe) ₂ SiO ₄
c.	Andalusite - - - - -	Al ₂ O ₃ , SiO ₂
	Kyanite - - - - -	As Andalusite
	Pycnite - - - - -	Al ₃ F, SiO ₄
	Topaz - - - - -	
	Zircon - - - - -	Zr ₂ SiO ₄
	Staurolite - - - - -	(H ₂ , Mg ₃ , Fe ₃ , Al ₂ , Fe 3 SiO ₄

H y d r o u s .

ne h 3.	Mineral.	Formula.	
	Analcime - - - -	$\text{Na}_2 \text{SiO}_3 + \text{Al}_2 3 \text{SiO}_3 + 2 \text{Aq}$	Int.
	Apophyllite - - -	$(\text{H}_2, \text{Ca}, \text{K}_2) \text{SiO}_3 + \text{H}_2 \text{SiO}_3$	Int.
	Brewsterite - - -	$[2 \text{H}_2 + (\text{Br Sr})] 3 \text{SiO}_3 + \text{Al}_2 3 \text{SiO}_3 + 3 \text{Aq}$	Int.
	Chabasite - - - -	$4 \text{Ca SiO}_3 + \text{Na}_2 \text{SiO}_3 + 5 (\text{Al}_2 3 \text{SiO}_3) + 30 \text{Aq}$	Int.
	Lapis Lazuli - - -	Indefinite, $\text{SiO}_2 \text{Al}_2 \text{O}_3, \text{Fe}_2 \text{O}_3, \text{CaO}, \text{Na}_2 \text{O}, \text{H}_2 \text{O}, \text{SO}_3$	
	Laumonite - - - -	$\text{Ca SiO}_3 + \text{Al}_2 3 \text{SiO}_3 + 4 \text{Aq}$	Int.
	Mesotype - - - -	$6 \text{H}_4 \text{SiO}_4 + 2 \text{Ca}_2 \text{SiO}_4 + \text{Fe}_2 \text{SiO}_4 + 3 \text{Al}_4 3 \text{SiO}_4 + 9 \text{Aq}$	Int.
	Natrolite - - - -	$2 \text{H}_4 \text{SiO}_4 + \text{Na}_4 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4 + 2 \text{Aq}$	Int.
	Prehnite- - - - -	$\text{H}_4 \text{SiO}_4 + 2 \text{Ca}_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4$	Int.
	Scolezite - - - -	$2 \text{H}_4 \text{SiO}_4 + \text{Ca}_2 \text{SiO}_4 + \text{Al}_4 3 \text{SiO}_4 + 2 \text{Aq}$	Int.
	Thomsonite - - - -	$3 \text{Ca}_2 \text{SiO}_4 + \text{Na}_4 \text{SiO}_4 + 4 \text{Al}_4 3 \text{SiO}_4 + 18 \text{Aq}$	Int.
	Datholite - - - -	$(\text{H}_2 + 2 \text{Ca} + \text{B}_2) \text{O}_2 2 \text{SiO}_4$	Int.
	Heulandite - - - -	$2 \text{H}_2 \text{SiO}_3 + (\text{Ca}, \text{Na}_2) \text{SiO}_3 + \text{Al}_2 3 \text{SiO}_3 + 3 \text{Aq}$	Int.
	Stilbite - - - - -	$2 \text{H}_2 \text{SiO}_3 + \text{Ca SiO}_3 + \text{Al}_2 3 \text{SiO}_3 + 2 \text{Aq}$	Int.
b.	Okenite - - - - -	$\text{Ca SiO}_3 + \text{H}_2 \text{SiO}_3 + \text{Aq}$	Int.

Fus. alone and with Na ₂ CO ₃ .	Mineral.	Formula.
I. b.	Pectolite - - - -	5 (Ca, Na ₂) SiO ₃ +H ₂ SiO ₃
c.	Saponite - - - -	{ Indefinite, SiO ₂ , Al ₂ O ₃ , Fe ₂ O ₃ , MgO, CaO, H ₂ O
II. a.	Antrimolite- - - -	As Mesotype
	Harmotome- - - -	{ H ₂ SiO ₃ +Ba SiO ₃ +Al ₂ 3 SiO ₃ +4 Aq
b.	Brevicite - - - -	As Natrolite
	Orthite - - - -	{ 3 (Ce, Fe, La, Di, Ca, Mg, H ₂) ₂ SiO ₃ +(Al, Fe) ₂ 3 SiO ₃ } I
III. c.	Pitchstone - - - -	{ Indefinite, SiO ₂ , Al ₂ O ₃ , Fe ₂ O ₃ , CaO, MgO, Na ₂ O, H ₂ O
	Talc to V. - - - -	H ₂ SiO ₃ +4 Mg SiO ₃
	Chlorite- - - -	(5 Mg+2 Al) O ₂ 3 SiO ₄ +4 Aq
	Pinite - - - -	H ₄ SiO ₄ +(K ₃ Al ₃) 3 SiO ₄
IV. a.	Steatite - - - -	As Talc or Saponite
c.	Gilbertite - - - -	{ Indefinite, SiO ₂ , Al ₂ O ₃ , FeO, MgO, CaO, H ₂ O } I
	Meerschaum - - - -	H ₂ SiO ₃ +2 Mg SiO ₃ +Aq
	Serpentine - - - -	H ₄ SiO ₄ +3 Mg ₂ SiO ₄ +2 Aq
V. a.	Gismondine- - - -	SiO ₂ , Al ₂ O ₃ , CaO, K ₂ O, H ₂ O

TABLE II.

Analcime	-	if transparent becomes white and opaque when heated, but on incipient fusion resumes its transparency and then fuses to a clear glass.
Andalusite	-	when powdered and treated with cobalt solution in charcoal, assumes a blue color.
Apophyllite	-	fuses to a frothy white glass.
Axinite	-	imparts a green color to the blowpipe flame, owing to the presence of boracic acid. This reaction is especially distinct, if the mineral be previously mixed with fluor-spar and bisulphate of potash.
Beryl	- -	sometimes gives a chromium reaction in borax and microcosmic salt.
Chabasite	-	fuses to a white enamel.
Chondrodite		evolves fluorine in the glass tube, both when heated alone, and with microcosmic salt. It sometimes also gives off a trace of water.
Chrysoberyl	-	is unattacked by carbonate of soda. With nitrate of cobalt on charcoal the finely powdered mineral assumes a blue color.
Datholite	-	fuses to a clear glass and colors the flame green.
Diallage	- -	frequently gives off water in small quantity.
Fuchsite	-	gives the chromium reaction in borax and microcosmic salt.

Gadolinite -	that from Hitteroe, if heated in a p covered platinum spoon to low r glows suddenly and brilliantly.
Hauyne - -	affords the sulphur reaction both on cl and when fused with potash. It co both sulphur and sulphuric acid.
Hypersthene	as Diallage.
Kyanite - -	as Andalusite.
Lapis Lazuli-	fuses to a white glass, and when t with carbonate of soda on charcoal the sulphur reaction on silver.
Laumonite -	when strongly heated exfoliates and cu
Lepidolite -	colors the blowpipe flame crimson lithia, also gives the fluorine reacti microcosmic salt.
Leucite - -	some varieties, when treated with solution, assume a blue color.
Meerschaum	in the glass-bulb frequently blacker evolves an empyreumatic odor. c organic matter. When this is bu it again becomes white, and if moi with nitrate of cobalt solution and l assumes a pink color.
Okenite - -	behaves as Apophyllite.
Olivine - -	some varieties give off fluorine, wher with microcosmic salt.
Pectolite- -	similar to Apophyllite.
Petalite - -	imparts a slight crimson color to the like Lepidolite.
Prehnite - -	as Chabasite.

Pycnite - -	assumes a blue color, when treated with nitrate of cobalt. Gives the fluorine reaction with microcosmic salt.
Pyrope - -	gives the chromium reaction with borax and microcosmic salt.
Scolezite - -	similar to Laumonite, but more marked.
Scapolite - -	occasionally contains a small quantity of lithia, and colors flame red when fused with fluor-spar and bisulphate of potash.
Sodalite - -	if mixed with $\frac{1}{5}$ its volume of oxide of copper, moistened to make the mixture cohere, and a small portion placed upon charcoal and heated with the blue oxidising flame, the outer flame will be colored intensely blue from chloride of copper.
Spodumene -	when not too strongly heated, colors the blowpipe flame red, when more strongly, yellow.
Stilbite - -	as Chabasite.
Topaz - -	when heated, remains clear. Otherwise as Pycnite.
Tourmaline -	gives the boracic acid reaction with fluor-spar and bisulphate of potash.
Wollastonite	colors the blowpipe flame faintly red from lime.
Zircon - -	the colored varieties become white or colorless and transparent, when heated. Is only slightly attacked by carbonate of soda.

C E R I U M.

(Behaviour in borax and microcosmic salt see page 58.)

The only important mineral of cerium besides Orthite (which has already been noticed among the earthy silicates) is Cerite $(\text{Ce, La, Di})_2 \text{SiO}_4 + \text{Aq}$, the blowpipe characters of which are as follows: — In the glass-bulb it evolves water and becomes opaque; on charcoal and in the forceps it is infusible; in borax and microcosmic salt it exhibits the characteristic reactions of the oxide of cerium, leaving in the latter case an insoluble skeleton of silica; and with carbonate of soda it forms a semi-fusible slaggy mass. In order to detect the lanthanum and didymium in cerite, a regular and carefully conducted analysis by the wet way is necessary, for the details of which see *Rose's* "Handbook of Analytical Chemistry."

U R A N I U M.

(Behaviour in borax and microcosmic salt see page 65.)

In the three principal uranium minerals—viz. Pitchblende, Uranium ochre, and Uranite—the presence of uranium is sufficiently indicated by the reactions these minerals afford with borax and microcosmic salt, and which are described at page 65. In the case of Chalcolite this uranium reaction is concealed by copper, which must therefore be removed before the reactions of the uranium can be observed. This may be done by reducing the copper upon charcoal in the manner described at page 81, after which the uranium reactions may be obtained by transferring the borax bead from the charcoal to a platinum wire. Oxide of uranium is distinguished from oxide of iron by the brilliancy of the green color it imparts to microcosmic salt in the reducing flame, and by the black color a borax bead saturated with this oxide assumes when submitted to an intermittent reducing flame.

Pitchblende never consists of pure oxide of uranium, but always contains more or less of some of the following bodies, viz: — iron, lead, copper, bismuth, manganese, cobalt, arsenic, lime, sulphur, silica, carbonic acid and water. Of these lead, iron, sulphur, arsenic, silica and water are those most constantly present, and the reactions of these have therefore been noticed in the following table. The presence of some of the others will of course modify the reactions considerably. — As regards the other minerals hereafter enumerated, the occasional impurities occurring in them are unimportant as affecting their behaviour before the blowpipe.

An uranium mineral which occurs but rarely, and

which is therefore not mentioned in the following table, is Johannite, a hydrous sulphate of uranium, which in many of its reactions resembles Chalcocite, but differs from that

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on ch
Pitchblende -	U_3O_8 essentially.	Evolved some water and a small quantity of sulphur, sulphide of arsenic, and metallic arsenic.	Evolved SO_2 and a white sublimate of arsenious acid.	Gives senica
Uranium ochre	$(U_2O_3)_3SO_3$ + 14 Aq.	Evolved water and assumes a red color.	—	In flame a green
Uranite - -	$2(U_2PO_8)$ + CuH_2O_2 + 7 Aq.	Evolved water and becomes yellow and opaque.	—	Fuses intum to a bl. havin crystals
Chalcocite -	$2(U_2PO_8)$ + CuH_2O_2 + 7 Aq.	As uranite.	—	As u

mineral in affording no phosphoric acid reaction, and in producing a black stain upon silver when fused with carbonate of soda and treated in the manner described at page 77.

Behaviour				(8) Special reactions.
(1) Reps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
I. the be- he as- ing to resence Some- also owards nt, due Cu.	The roasted mineral affords the uranium reaction.	As borax. Also a small residue of silica.	Infusible. Affords the characteristic Pb incrustation, and sometimes yields minute particles of Cu.	—
-	Gives the uranium reaction.	As in borax.	—	—
-	In the oxidising flame gives a green bead, which in the reducing flame becomes of an opaque red from Cu.	As in borax.	In reducing flame yields a metallic bead of Cu.	Gives the PO_5 reaction (p. 94)
-	Gives the uranium reaction.	As in borax.	Forms an infusible yellow slag.	As uranite.

I R O N.

(Behaviour in forceps see p. 60, in borax and microcosmic salt see with carbonate of soda p. 75, special reaction p. 81.)

Oxide of iron is easily distinguished from other tallic oxides by its reactions in borax and microcosmic in the oxidising and reducing flames, and by forming incrustation upon charcoal when treated with carbona soda. It is present in most mineral substances, either an essential or accidental ingredient, but those only which it forms a principal element are recognised as

Mineral.	Formula.	Behaviour	
		(1) in glass-bulb.	(2) in open tube.
Iron pyrites -	FeS_2 .	Gives a considerable yellow sublimate of sulphur and sometimes sulphide of arsenic. Also HS .	Sulphurous acid and sometimes arsenious acid are evolved.
Magnetic pyrites - }	$(\text{FeS})_5 \text{Fe}_2 \text{S}_3$	—	Evolves sulphurous acid.

minerals proper, and as such included in the following tables. The native oxides of iron become more or less infusible when treated in the outer oxidising flame, but, when heated in the inner blue flame, they become slightly fusible and magnetic (see page 42). Most of the silicates also fuse and become magnetic when treated on charcoal in a similar manner, as likewise do the sulphides and arsenides of iron. Of the sulphates, phosphates and arseniates, some afford a magnetic bead when fused alone on charcoal in the reducing flame, and some when similarly treated with carbonate of soda.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The roasted mineral gives a strong iron reaction.	As in borax.	Fuses to a black mass, which spreads out on charcoal and gives the sulphur reaction on silver.	—
—	As iron pyrites.	As in borax.	As iron pyrites.	—

I R O N. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char.
Mispickel -	$\text{Fe As}_2 + \text{FeS}_2$	A red sublimate of AsS_3 is first formed and then a black sublimate of metallic arsenic.	Sulphurous and arsenious acids are evolved, the latter forming a white sublimate.	Gives off arsenic, forming an incrust and forming a mass of globules.
Magnetic iron ore - - -	Fe_3O_4	—	—	—
Specular iron Red hæmatite	Fe_2O_3	—	—	—
Göthite - -	$\text{Fe}_2\text{H}_2\text{O}_4$	Evolves water	—	—

ages 144 and 145.)

Behaviour				(8) Special reactions.
(4) reeps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	As iron pyrites.	As in borax.	As iron pyrites.	—
e blue fuses on and re- mag- netic.	Gives the iron reaction.	As in borax.	—	—
V. e blue is con- into , and behaves e pre- ling.	As magnetic iron ore.	As in borax.	—	—
specular ron.	As specular iron.	As in borax.	—	—

IRON. (Contin

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Franklinite -	$(\text{Fe}, \text{Zn}, \text{Mn})$ $(\text{Fe}_2\text{Mn}_2)\text{O}_4$	—	—	Forms incrustations on the coal, moist with solution assumes color (s
Ilmenite -	$\text{Ti}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	—	—	-
Chromic iron -	$\text{Fe}, \text{Cr}_2\text{O}_3$	—	—	.
Lignite -	$(\text{Ca}, \text{Fe})_2\text{Si}_2\text{O}_7 + \text{Fe}_2\text{O}_3$	Occasionally gives off some water and turns black.	—	Fuses black which reduces to black

ges 146 and 147.)

Behaviour				(8) Special reactions.
(4) recept.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V. the flame edges becomes netic.	Gives the iron and mangan- ese reaction.	As in borax.	Affords a con- siderable white incrus- tation of ZnO.	Gives a strong manganese reaction with nitre and car- bonate of soda (see page 81).
lucing uses on and be- mag- c.	Gives the iron reaction.	In oxidising flame exhibits the iron reac- tion. In re- ducing flame assumes a deep brownish red color.	—	—
pre- g.	Dissolves slowly and gives the chromium re- action.	As in borax.	On platinum foil with nitre and carbonate of soda affords a yellow mass of chromate of potash.	—
lucing mag- ic.	Gives the iron reaction.	Gives the iron and silica re- actions.	Fuses to a black opaque bead.	Generally gives the manganese reaction with nitre and car- bonate of soda.

I R O N. (Contin

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on ch
Chloropal - -	$2(\text{Fe}_2 3 \text{SiO}_3) + 9 \text{Aq.}$	Decrepitates more or less, gives off much water and turns black.	—	-
Green earth -	$\text{SiO}_2, \text{FeO}, \text{Al}_2\text{O}_3, \text{Na}_2\text{O}, \text{K}_2\text{O}, \text{H}_2\text{O}.$	Gives off water and becomes darker in color.	—	.
Siderite - -	FeCO_3	Occasionally decrepitates. Gives off CO_2 and turns black and magnetic.	—	As in bi

ages 148 and 149.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V. es color l turns black.	Gives the iron reaction.	Gives the iron and silica reactions.	Fuses to a transparent green glass.	—
V. reducing ne fuses edges, and ors the er flame ow (Na_2O) iolet (K_2O)	As the pre- ceding.	As the pre- ceding.	Forms a slaggy mass.	—
aves simi- y to the gnetic oxide.	Gives the iron andsometimes manganese reaction.	As in borax.	Behaves as an oxide. With nitre and car- bonate of soda on platinum generally gives the manganese reaction.	In acid dis- solves with effervescence.

I R O N. (Conti

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on c
Copperas - -	$\text{Fe SO}_4 + 7 \text{ Aq.}$	Gives off water, and, when strongly heated, SO_2 and H_2SO_4 , which redden litmus paper.	Evolves water and SO_2 , which may be recognised by its odor.	Loses and is c into
Vivianite - -	$\text{Fe}_3 2 \text{ PO}_4 + 8 \text{ Aq.}$	Gives off water.	—	Froth then, a gre lic
Triphylite- -	$(\text{Fe, Mn, Li}_2)_3 2 \text{ PO}_4$	Gives off water having an alkaline reaction, and assumes a metallic lustre resembling graphite.	—	Fuse to magr with lic

res 150 and 151.)

Behaviour				(8) Special reactions.
4) reeps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
off H_2O O_3 , and behaves mag- oxide.	The roasted mineral affords an iron reac- tion.	As in borax.	Forms sul- phide of so- dium and oxide of iron. The former is absorbed into the char- coal, and if cut out and laid upon silver and moistened gives the S-reaction.	If dissolved in water, and a strip of silverfoil be introduced into the solu- tion, the me- tal remains untarnished (see p. 85).
char- Singes green (O_3).	Gives the iron reaction.	As in borax.	In reducing flame becomes magnetic and fuses to a black slaggy mass.	—
I. latinum dors the crim- (O) and (P_2O_5), is the uses to a magnetic ad.	Gives the iron and mangan- ese reactions.	Gives the iron reaction, which overpowers that of the manganese.	Forms an in- fusible porous mass, which under the re- ducing flame becomes mag- netic.	Gives the manganese reaction with nitre and car- bonate of soda on platinum foil.

I R O N. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Scorodite - -	$\text{Fe}_2 \cdot 2 \text{AsO}_4$ + 4 Aq.	Evolves water	Gives off water and AsO_3 .	Emits aral fumes in the ring fuses (magnetic having metallic lu
Cube ore - -	$3 (\text{Fe}_2 \cdot 2 \text{AsO}_4)$ + $\text{Fe}_2 \text{H}_3 \text{O}_6$ + 12 Aq.	Evolves much water.	As the preceding.	As the cedin

The arsenides and sulphides of iron occasionally contain small quantities of cobalt and nickel. In iron pyrites copper is also occasionally present. The native oxides, as well as the silicates and some other iron minerals, generally contain more or less manganese, and the silicates, carbonates and sulphates also frequently contain a certain proportion of magnesia and lime. Spathic iron (siderite) indeed passes by insensible gradations on the one hand into carbonate of manganese, and on the other into dolomite and calc-spar.

Besides the minerals enumerated in the above table, the following are of importance:—Leucopyrite (Fe As),

pages 152 and 153.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
I. on char- Colors water flame blue.	The roasted mineral gives an iron reaction.	As in borax.	As alone on charcoal.	Gives the arsenic reactions (see p. 92).
the pre- ceding.	As the pre- ceding.	As in borax.	As the pre- ceding.	As the pre- ceding.

which behaves somewhat similarly to mispickel, except that containing but a small quantity of sulphur, a considerable sublimate of metallic arsenic is formed from it in the glass-bulb, and in the open tube it evolves but little SO_2 :—Brown hæmatite or Limonite ($\text{Fe}_2 \text{H}_3 \text{O}_9$), which behaves as goëthite, and differs from that mineral solely in the relative proportions of the iron and water:—Iserine, $\text{Fe}(\text{Fe}_2 \text{Ti}_2) \text{O}_6$, which behaves as Ilmenite:—Cronstedite, Hisingerite, and Crocidolite, hydrous silicates of iron, containing more or less magnesia and lime. Crocidolite also contains about 7 % of soda, and therefore imparts a yellow color to the blowpipe flame. Before the blowpipe these

silicates behave in a similar manner to Chloropal, with the exception that the fusibility of Crocidolite is II., that of Cronstedite III., and that of Hisingerite IV. — Pitticite and Diodochite, the former an amorphous arsenio-sulphate, the latter a phosphato-sulphate of iron, and both containing a considerable quantity of water: — and Pyrosmalite, a hydrous chloro-silicate of iron, which is characterised by giving off a yellow chloride of iron when strongly heated in the glass-bulb, and by affording the various chlorine reactions detailed at page 88.

M A N G A N E S E.

(Behaviour in borax and microcosmic salt see p. 59, with nitre and carbonate of soda p. 81.)

By the reactions of oxide of manganese in borax and microcosmic salt, and by the characteristic green color it produces when fused with nitre and carbonate of soda, this oxide may at all times be detected in mineral substances, even when present in very small quantity only. The amethystine color it imparts to borax, and which disappears in the reducing flame, is very characteristic, when no other powerfully coloring oxide is present: but if cobalt be present, or even iron in large quantity, the other process must be resorted to for its detection.

Of the following minerals Rhodonite contains from 2 to 13% of lime, and generally a certain proportion of iron, which, if in sufficient quantity, renders the mineral

magnetic when fused in the blue flame. Diallogite contains carbonate of iron, carbonate of lime and carbonate of magnesia in variable proportion, and according to the percentage of these salts passes into siderite and dolomite.

Besides the manganese minerals afterwards mentioned, the following are important: of oxides, Hausmannite (Mn_2O_4) and Braunite (Mn_2O_3), which behave before the blowpipe in a similar manner to Manganite, but give less water; Polianite, which resembles Pyrolusite in its reactions and is probably merely a variety of that mineral, and Crednerite, $(Ba, Cu)_2 Mn_4 O_9$, which is characterised by affording a mixed manganese and copper reaction with borax and microcosmic salt, and a bead of metallic copper when treated with the reducing flame upon charcoal; of carbonates, Manganocalcite, which differs from Diallogite principally in its form of crystallization, and possesses the same blowpipe characters as that mineral.

Of other manganese minerals, Franklinite and Triphylite are described under Iron (p. 144), and such polybasic silicates as manganesian garnet and manganesian epidote are included as varieties of garnet, epidote, etc., in the table of the earthy and alkaline silicates given at p. 132.

MANGANESE. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Manganblende	Mn S.	—	Gives off SO ₂ and becomes greyish green on surface.	Is roasted and converted into MnO ₂ .
Pyrolusite	Mn O ₂	Frequently gives off a small quantity of water, and, when strongly heated, oxygen.	—	—
Manganite	Mn ₂ H ₂ O ₄	Gives off much water.	—	—
Psilomelane	(Ba, Mn, K) MnO ₃ + Mn ₂ O ₃ + nAq.	Gives off water, and, when strongly heated, oxygen.	—	—

MANGANESE. (Continu

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on cha
Wad - - -	$\text{MnO}_3, \text{MnO},$ H_2O also $\text{Fe}_2\text{O}_3, \text{Al}_2\text{O}_3,$ $\text{BaO}, \text{CuO},$ $\text{PbO}_3, \text{SiO}_3$ etc.	Gives off water.	—	—
Rhodonite - -	Mn SiO_3	Gives off more or less water.	—	Under a flame fu brown bes
Diallogite - -	Mn Co_3	Frequently decrepitates and gives off more or less water.	—	If str heated moisten an alk reacti litmus due to t sence of
Triplite - -	$(\text{Mn Fe})_3$ $2\text{PO}_4 + (\text{Ca},$ $\text{Mg}, \text{Fe}) \text{F}.$	Generally gives off more or less water.	—	—

ages 158 and 159.)

Behaviour				(8) Special reactions.
(4) orcepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V. s flame isly ac- g to its osition.	Gives the manganese reaction more or less modified by the presence of other oxides.	As in borax.	As pyrolusite.	Various according to composition. When strongly heated and then moistened has an alkaline reaction on red litmus paper.
I. char- al.	In the oxidising flame gives the manganese reaction. In reducing flame the iron reaction more or less intense.	As in borax, but leaves an insoluble siliceous skeleton.	With a small quantity of the alkali fuses to a black bead. With a larger quantity forms a slag.	—
7. iently s the slightly ad.	Gives the manganese and iron reactions.	As in borax.	Forms an infusible slag.	In warm acid dissolves with much effervescence.
I. s the blow- flame (P ₂ O ₅).	Gives the manganese and iron reactions.	As in borax.	Forms an infusible mass.	—

CHROMIUM.

(Behaviour in borax and microcosmic salt see p. 74.)

The oxide of chromium is readily detected in its minerals by the very characteristic green color it imparts to borax and microcosmic salt, more especially in the reducing flame. The only important mineral of chromium besides those enumerated below, and which are described in other parts of this work, is chrome ochre, a hydrous silicate of chromium, alumina and iron. Before the blowpipe it exhibits the following characters:—In the glass-bulb it gives off water and becomes colorless. In the forceps it frits on the surface, but does not fuse. In borax and microcosmic salt it dissolves with difficulty, giving a chromium reaction, and in the latter salt a siliceous skeleton remains undissolved. With a considerable amount of carbonate of soda it fuses with difficulty to a dusky green enamel.

The mixed silicates, Fuchsite, Pyrope, etc., are treated of in the section on Silicates (see page 129). For chrome iron, see Iron, page 148; and for chromate of lead, see Lead, page 180.

NICKEL AND COBALT.

(Behaviour in borax and microcosmic salt see p. 60, with carbonate of soda p. 75. Mode of detecting nickel in the presence of cobalt p. 82.)

These two metals are so nearly allied to each other, and so frequently occur replacing one another in the same mineral, that it is hardly possible to treat of the minerals of one as regards their blowpipe characters without at the same time describing those of the other. The color imparted by cobalt to borax glass, and which remains unchanged in the reducing flame, is most characteristic, and is so intense as to overpower or greatly modify that produced by other metallic oxides. It is easily distinguished from the blue color produced by the oxide of copper by undergoing no change in the reducing flame, or on charcoal; and when existing in any mineral together with that oxide, the latter may be removed by a reduction on charcoal, and the cobalt color will then be perceptible in the reducing as well as in the oxidising flame. The color of nickel in borax is also characteristic, but is not very powerful, and if cobalt be present even in small quantity, is scarcely to be recognised. Under such circumstances the process described at page 82 must be resorted to for its detection.

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Millerite - -	Ni S.	—	Evolves SO_2 .	Fuses much to netic
Copper nickel-	Ni As.	Gives off a little As O_3 .	Gives off much As O_3 and some SO_2 and falls to powder.	Fuses with magnetite color flame
Smaltine - -	(Co, Fe, Ni) As_2 .	When strongly heated generally evolves metallic arsenic.	Gives a crystalline sublimate of As O_3 . Also some SO_2 .	Gives off arsenic fuses to grey bead, brittle flame

Behaviour				(8) Special reactions.
4) recepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The roasted mineral gives a nickel reaction, slightly modified by small quantities of iron and copper.	As in borax.	Fuses to a slaggy mass which on silver gives the sulphur reaction.	—
—	The arsenical bead obtained by fusing the mineral on charcoal, if fused upon the same support with borax successively added and removed, gives firstly an iron reaction, then cobalt if present, and lastly nickel.	If the residual bead which has been treated with borax be further treated with microcosmic salt, the nickel reaction will be obtained and sometimes a slight copper reaction.	—	Affords a sublimate of metallic arsenic when treated as described at page 92.
—	As the preceding, but the cobalt being in large excess requires some time for its perfect oxidation before the nickel-reaction is exhibited.	Gives the 'cobalt-reaction, and after the cobalt has been removed, that of nickel.	—	As the preceding.

NICKEL AND COBALT

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Glance cobalt -	Co S_2 + Co As_2	—	As the preceding, but gives off more SO_2 .	Gives and As fuses in a glass bead. flame
Nickel glance -	Ni S_2 + Ni As_2	Decrepitates and gives an orange-colored sublimate of As S_3 .	As the preceding.	As the preceding.
Ulmannite -	Ni S_2 + Ni (As Sb)_4	Gives a slight white sublimate of Sb O_3 and more or less As S_3 .	Gives off thick fumes of Sb O_3 and Sb O_5 with As O_3 and SO_2 .	As glance, but with a denser sublimate of Sb

tinuation of pages 164 and 165.)

Behaviour				(8) Special reactions.
(4) recepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	Gives a cobalt and slight iron reaction when treated as the preceding minerals.	As in borax.	Gives a sulphur-reaction of silver.	As the preceding.
—	As copper nickel.	Gives the nickel reaction, occasionally somewhat obscured by cobalt.	As the preceding.	As copper nickel.
—	As copper nickel.	As the preceding.	As the preceding.	As copper nickel generally, but arsenic is not always present.

NICKEL AND COBAL

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Cobalt pyrites	$2(\text{Co, Ni, Fe, Cu})\text{S} + \text{CoS}_2$	When strongly heated gives off sulphur and becomes brown.	Gives off much S O_2 and a small quantity of As O_3 .	In the ring flask small fragments of with the lution of phur to a netic b having bronze-co fractur
Emerald nickel	Ni CO_3 + $2 \text{Ni H}_2 \text{O}_2$ + 4 Aq.	Gives off much water and turns black.	—	—
Cobalt bloom -	$\text{Co}_2 2 \text{As O}_4$ + 8 Aq.	Gives off water.	—	Evolves a ical fu and in reducing fuses to a grey bea arsenide cobalt

uation of pages 166 and 167.)

sps.	Behaviour			(8) Special reactions.
	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
	In the oxidising flame on charcoal gives a violet-colored glass. In the reducing flame the nickel is reduced and may be collected in a gold bead as described at p. 82. When the nickel is removed, the glass exhibits a slight iron reaction while warm.	As in borax, but the reduction of the nickel is more difficult than in the latter flux.	As glance cobalt.	As copper nickel, but the amount of arsenic is usually very small.
	Dissolves with much effervescence, and gives the nickel reaction.	As in borax.	Forms a slaggy mass.	In warm dilute HCl dissolves with much effervescence.
point , blue fuses ours the flame (As).	Gives the cobalt reaction.	As in borax.	—	Gives off arsenic when treated as described at p. 92.

NICKEL AND COBA

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Earthy cobalt-	Indefinite, Mn O, Co O, Cu O, Fe O, H ₂ O, etc.	Gives off water.	—	Emits a smell of senic, but not fu

Of the above minerals copper nickel frequently contains small quantities of antimony, iron, lead and sulphur. Also occasionally a trace of cobalt. Small quantities of copper are occasionally found in many of the above minerals.

There are some other arsenides and sulphides of cobalt and nickel besides those mentioned in the table,

continuation of pages 168 and 169.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
lors the ame blue.	In oxidising flame gives the cobalt reaction, which obscures those of MnO , CuO , etc. In reduc- ing flame oc- casionally gives the CuO - reaction.	As in borax. If a saturated bead be treat- ed on char- coal with tin in the reduc- ing flame for a few seconds, the CuO -reac- tion is some- times obtained.	Forms an in- fusible mass.	With carbon- ate of soda and nitre on platinum foil gives a strong manganese reaction.

but they are too rare to require special notice in this place. — Nickel ochre is an arseniate corresponding both in composition and blowpipe characters to cobalt bloom, with the exception that the colors imparted by it to borax and microcosmic salt are those of nickel, occasionally somewhat modified by the presence of a small quantity of cobalt.

Z I N C.

(Behaviour on charcoal p. 27, in borax and microcosmic salt p. 62, with carbonate of soda p. 75, with nitrate of cobalt p. 91.)

The incrustation of oxide of zinc formed upon charcoal when any zinc mineral is heated in the reducing

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Zincblende -	Zn S.	Decrepitates strongly.	Evolves SO and becomes white or yellow if containing iron.	V. In the reducing flame forms a crust of ZnO; with Cd that metal is pressed
Red oxide of zinc - - -	ZnO.	—	—	In the reducing flame forms a crust of oxide of zinc on charcoal
Electric calamine- - -	$\text{Zn}_2\text{SiO}_4 + \text{Aq.}$	Gives off water and becomes white and opaque.	—	—

flame with carbonate of soda, is the most certain indication of the presence of that metal. The oxide is characterised by being yellow in the hot state, and white when cold, and by assuming a beautiful green color when moistened with nitrate of cobalt and strongly heated.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The roasted mineral gives a zinc-reaction and sometimes a slight iron-reaction.	As in borax.	As alone on charcoal. Moreover colors the flame blue. The fused alkali gives a S-reaction on silver.	—
V.	Generally gives a manganese- and slight iron - reaction in addition to that of zinc.	As in borax.	On charcoal forms a thick incrustation of Zn O.	With carbonate of soda and nitre on platinum foil gives a manganese - reaction.
V.	Dissolves to a clear glass, which cannot be rendered opaque by the intermittent flame.	Dissolves to a clear glass, which becomes opaque on cooling. Silica mains insoluble.	With carbonate of soda alone is infusible. With 2 parts of alkali and 1 of borax fuses to a glass and sets free Zn O, which incrusts the charcoal.	—

Z I N C. (Continuat

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Calamine - -	Zn CO_3	Gives off CO_2 and becomes opaque.	—	As the oxide. So times : gives a mium- : lead-incru tion.

Electric calamine sometimes, but rarely contains lead ; also small quantities of iron and carbonic acid. Calamine almost invariably contains more or less iron and manganese ; sometimes in considerable proportion. When a large amount of iron is present, as in the calamine of Altenberg, the mineral assumes a dark color in the glass-bulb and becomes magnetic. Magnesia, lime, and silica are moreover frequently found in this mineral.

Willemite is an anhydrous silicate of zinc ($\text{Zn}_2 \text{SiO}_6$) and resembles electric calamine in all its blowpipe characters, except that it gives no water in the glass-bulb.

Franklinite, a compound oxide of iron manganese and zinc, is described under the first of these metals. For zinciferous spinel (Automolite), see Alumina, page 128.

ges 172 and 173.)

Behaviour				(8)
(4) orcepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	Special reactions.
V.	Gives a zinc reaction and frequently an iron- and manganese - reaction.	As in borax.	Forms a thick incrustation of zinc, sometimes also of PbO CO.O	Dissolves with much effervescence in cold acid.

C A D M I U M.

(Behaviour on charcoal page 27, in borax and microcosmic salt p. 63, with carbonate of soda p. 75.)

The most important character of cadmium is that when heated upon charcoal alone, if in the metallic form, or with carbonate of soda, if in combination with other bodies, it incrusts the surface of the support with its characteristic reddish brown oxide. There is but one mineral of cadmium at present known, viz. Greenockite (Cd S), which is moreover of extremely rare occurrence. This mineral may be easily recognised by its behaviour with carbonate of soda upon charcoal, and may be distinguished from Cadmiferous Blende by forming no zinc incrustation on the charcoal after prolonged treatment upon that support.

B I S M U T H.

(Behaviour on charcoal p. 26, in borax and microcosmic salt p. 65, with carbonate of soda p. 75, with nitric acid p. 83.)

The incrustation of the oxide of this metal, which is formed upon charcoal, is very characteristic, unless the metal be present in very minute quantity or alloyed with a large proportion of lead. In such cases recourse may be had to the process described at page 83, which is very

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Native bismuth	Bi.	—	Fuses and is converted into a yellow oxide.	Fuses, bead and incrusts charcoal oxide
Bismuthine	Bi ₂ S ₃ .	—	Fuses with ebullition and gives off S and SO ₂ .	Fuses, much spires and in the reducing yields a tallic bead incrusts charcoal oxide
Bismuthblende	Bi ₂ Si ₂ O ₃₀ .	Turns yellow, and, when strongly heated, fuses.	—	Fuses, ebullition, brownish forming incrustation Bi ₂ O ₃ on charcoal

certain in its results, and requires only a minute fragment of the metal or alloy for its successful performance. In the case of a mineral, a metallic bead must be first obtained by a reduction upon charcoal with carbonate of soda, and this bead submitted to the test. — The brittleness of the bead so obtained is another, but less certain, indication of the presence of bismuth, since antimony and arsenides have equally the property of extreme brittleness. The following are the principal minerals of Bismuth.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The oxide formed upon charcoal gives the bismuth reactions.	As in borax.	—	—
—	The oxide obtained upon charcoal gives the bismuth reactions.	As in borax.	As alone on charcoal. The fused alkali gives the sulphur reaction on silver.	—
I. as with to a yellow bead, cooling the flame is green, specially if distended by H Cl. color is to P_2O_5 .	Gives the bismuth, and also an iron reaction.	As in borax, but leaves a siliceous skeleton.	Fuses to a yellow mass. The bismuth is then reduced to the metallic state and partially volatilised, incrusting the charcoal beyond.	—

BISMUTH. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Tetradymite -	$\text{Bi}_2 (\text{TeS})_3$	Occasionally decrepitates and then fuses, forming a greyish white sublimate immediately above the mineral fragment.	Fuses and gives off white fumes, part of which pass up the tube and part deposit immediately above the mineral. This latter if heated fuses to clear drops (TeO_3). The mineral residue becomes surrounded by fused $\text{Bi}_2 \text{O}_3$, characterised by its yellow color.	Fuses metallic colors outer bluish (Te and and in the char around the or $\text{Bi}_2 \text{O}_3$, be which white in tation 1 consistin TeO

Bismuth blende, in addition to bismuth, silica, phosphoric acid, and iron, contains oxide of manganese, a little water and fluorine, all of which may be readily detected by the

ages 176 and 177.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The yellow oxide obtained upon charcoal gives the bismuth reaction, and the white incrustation that of bismuth and telluric acid.	As in borax.	In the reducing flame yields a bead of metallic bismuth, part of which is with part of the tellurium volatilised, and incrusts the charcoal around.	The fused alkaline mass gives the sulphur-reaction on silver. Also gives the tellurium-reaction with charcoal and carbonate of soda (see p. 76).

ordinary means. Tetradymite frequently contains selenium and silver.

L E A D .

(Behaviour on charcoal p. 27, in borax and microcosmic salt p. 61
with carbonate of soda p. 75, in nitric acid p. 83.)

The principal blowpipe characters, by which the
minerals of this important metal may be recognised,

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	c
Galena - -	Pb S.	Generally decrepitates and gives off a small quantity of sulphur.	Gives off SO_2 , and when strongly heated, a white sublimate of PbSO_4 .	F re in m ar ar tic on co th f
Clausthalite -	Pb Se.	Decrepitates slightly.	Forms a sublimate of selenium, which is grey when thickly deposited, and red when thin (see p. 21).	Gi s st se co fla In in pa in ch Se Af tir int alc

that, when fused with the reducing flame, some alone and some with carbonate of soda, upon charcoal, they afford a metallic bead of lead (more or less malleable according to its purity), and an incrustation of oxide of lead, which is of a dark yellow color while warm, but becomes paler on cooling. Moreover, when touched with the blue oxidising flame, it imparts a blue color to the outer flame.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The oxide formed upon charcoal gives the lead-reaction.	As in borax.	As alone on charcoal. The fused alkali gives a sulphur-reaction on silver.	—
—	The infusible residue obtained upon charcoal gives an iron-and-sometimes copper-and cobalt-reaction.	As in borax.	With carbonate of soda or oxalate of potash yields a metallic bead, the fused alkali laid upon silver and moistened produces a stain similar to that produced by sulphur. (see p. 77).	—

LEAD. (Conti

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on c
Jamesonite -	$2 (\text{Pb, Fe, S}) + \text{Sb}_2 \text{S}_3$	Fuses and gives off some sulphur, sulphide of antimony and antimony, which condense in the neck of the bulb (see p. 23).	Fuses and emits dense white fumes of SbO_3 , which pass off and redden blue litmus paper.	Fuses and gives off dense white fumes of SbO_3 , which pass off and redden blue litmus paper.
Minium - -	Pb_3O_4	—	—	Is first (Pb) then talli which the cru
Mendipite - -	$\text{PbCl}_2 + 2 \text{PbO}$	Decrepitates slightly, and assumes a yellow color.	—	Fuses and is to n lead evolu acid Form incr of Pl a yel of

ages 180 and 181.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The yellow incrustation formed upon charcoal gives the reaction of lead, and the white those of antimony.	As in borax.	As alone on charcoal. The fused alkali gives the sulphur-reaction on silver.	—
ors the r flame blue.	Gives the lead-reactions.	As in borax.	As alone on charcoal.	—
the pre- ceding.	As the pre- ceding.	As in borax.	As alone on charcoal.	Gives the chlorine reaction with CuO and microcosmic salt (see p. 88).

LEAD. (Continu

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on cha
Cerussite - -	Pb CO_3	Decrepitates, gives off CO_2 , turns yellow and fuses.	—	Is redu metallic incrusti ch a r around Pb
Anglesite - -	Pb SO_4	Decrepitates and gives off a small quan- tity of water.		In the c ing flam to a clear which be opaque cooling. reducing is red with ebullitic metallic and in the ch around Pb

, 182 and 183.)

Behaviour				(8) Special reactions.
ps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
pre- g.	Givesthelead- reaction.	As in borax.	As alone on charcoal.	In nitric acid dissolves with much effervescence.
pre- g.	Givesthelead- reaction, and occasionally a slight iron and manganese- reaction.	As in borax.	Is reduced yielding a me- tallic lead- bead. The fused alkaline mass gives a sulphur-reac- tion on silver.	—

LEAD. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on charcoal.
Pyromorphite	$\text{Pb Cl}_2 + 3 (\text{Pb}_3 2 \text{PO}_4)$	Decrepitates, and when strongly heated for some time, gives a slight white sublimate of Pb Cl .	—	In flame a bead on charcoal. Surface cooling forms film on charcoal. Reducing fuses and reduces on charcoal. Consumes hydrogen. Increases weight slightly.
Mimetene	$\text{Pb Cl}_2 + 3 (\text{Pb}_3 2 \text{AsO}_4)$	As the preceding.	—	Fuses easily. The product gives and the with Final duces metal and increases of

res 184 and 185.)

Behaviour				(8) Special reactions.
4) repts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
and co- e flame ue.	—	—	Is reduced yielding a metallic bead and incrusting the charcoal with PbO.	Gives the chlo- rine - reaction with micro- cosmic salt and Cu O (see p. 88). Also the phosphoric acid reactions (see p. 94).
As pre- ceding.	The oxide formed on charcoal gives the lead-reac- tions.	As in borax.	As the pre- ceding.	Gives the chlorine-reac- tion (see p. 88).

LEAD. (Contd.)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on c
Vanadinite -	$3 \text{ Pb VO}_3 + \text{Pb Cl}_2$	As pyromorphite.	—	The mine to shini whic redu affor tall Incre char with film and wit
Crocoisite -	Pb CrO_4	Decrepitates violently and assumes a dark color.	—	Fuse tona ing met and an tion on

ges 186 and 187.)

Behaviour				(8) Special reactions.
4) recepts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
romor- ite.	Dissolves readily to a clear glass, which in the oxidising flame is yellow while hot, and colorless when cold. In reducing flame becomes opaque and on cooling green (see p. 73).	In oxidising flame is yellow while hot, becoming paler on cooling. In reducing flame brown while warm, and emerald green when cold (see p. 73).	On platinum wire fuses to a yellow bead, which is crystalline on cooling. On charcoal yields a button of metallic lead.	With microcosmic salt and CuO , gives the chlorine reaction. If fused in a platinum spoon with from 3 to 4 times its volume of KHSO_4 , it forms a fluid yellow mass having an orange color when cold.
romor- ite.	Dissolves readily and colors the glass yellow while warm, and green when cold (see chromium p. 74).	As in borax (see chromium-reaction p. 74.)	On platinum foil gives a dark yellow mass, which becomes paler on cooling. On charcoal yields a metallic button.	Treated as above with KHSO_4 forms a violet colored mass, which on solidifying becomes reddish and on cooling pale grey.

LEAD. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Molybdate of lead	Pb MO_4	As the preceding.	—	Fuses and partly absorbed into charcoal, leaving a globule of metallic lead, which is partially disintegrated and encrusted with charcoal.
Scheelite -	Pb WO_4	Decrepitates more or less.	—	Fuses to a bead increasing the coal with it. The bead on cooling is tall and has a metallic face.

All lead minerals contain more or less silver, as may be ascertained by cupelling carefully the metallic lead obtained from this. The percentage of this metal is very variable, and is frequently not to be detected, unless a large quantity of the mineral be examined for its presence, but is sometimes considerable, especially in galena, tinter

ages 188 and 189.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
pyromor- phite.	Dissolves readily and gives the molybdena reaction.	As in borax.	Yields metallic lead.	Fused as above with KHSO_4 forms a yellow mass, which becomes white on cooling. If this be dissolved in water and a piece of zinc introduced into the solution, the latter becomes blue.
pyromor- phite.	Dissolves to a clear colorless glass, which in the reducing flame becomes yellow and on cooling grey and opaque.	Dissolves to a clear colorless glass, which in the reducing flame assumes a dusky blue color. After a time becomes opaque.	As the preceding.	With carbonate of soda and nitre gives the manganese reaction.

ore, and some of the antimonial sulphides. — Of the individual minerals, Clausthalite contains occasionally small quantities of copper and cobalt. — Pyromorphite, although given in the table as a pure chloride and phosphate of lead, frequently contains a considerable amount of arsenic, and then exhibits the mixed blowpipe characters of the

phosphate and arseniate of lead. Phosphate of lime, fluorine, and iron are moreover frequently present in this mineral. The former sometimes amounting to 11 %.

Besides the lead minerals already enumerated, there are many others of considerable importance. Such are:—Foliated tellurium, which is easily recognised by its characteristic tellurium-reactions, and contains about 9 % of gold with smaller proportions of copper and silver (see gold, page 232). — Zinkenite, Heteromorphite, Boulangerite, Plagionite and Geocronite, which are essentially antimonial sulphides of lead, but generally contain a small quantity of copper and iron; also in the case of Geocronite, arsenic. They resemble Jamesonite in their behaviour before the blowpipe, but differ somewhat in their relative fusibility.—Corneous lead ($\text{PbCO}_3 + \text{PbCl}_2$), which behaves like Mendipite before the blowpipe, but may be distinguished from the latter by its effervescing in nitric acid.—Linneite ($\text{PbSO}_4 + \text{CuH}_2\text{O}_2$), which resembles Anglesite in its blowpipe characters, but when fused with boracic acid on charcoal yields a small bead of copper.—Leadhillite ($\text{PbSO}_4 + 3\text{PbCO}_3$) and Lanarkite ($\text{PbSO}_4 + \text{PbCO}_3$), which present the mixed characters of Anglesite and Cerusite.

For Bournonite see Copper, page 193.

C O P P E R.

(Behaviour of the oxide on platinum wire p. 36, of the chloride and bromide p. 40, in borax and microcosmic salt p. 66, with carbonate of soda p. 75.)

The most characteristic reaction afforded by copper and its minerals before the blowpipe is that exhibited by them when fused with borax and microcosmic salt, which affords a ready means of detecting copper even in the presence of all other metals. The colors imparted by the oxide and chloride to the blowpipe flame are also characteristic, more especially the latter; and the test recommended for chlorine, and described at page 88, is, *mutatis mutandis*, equally applicable as a test for the oxide and other combinations of copper. The copper minerals are very numerous, and as many of them exhibit precisely similar blowpipe characters, a knowledge of their physical characters is indispensable to enable the student to distinguish such species. The following are the most important copper minerals.

BEHAVIOUR OF MINERALS

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal.
Native copper -	Cu.	—	—	Fuses to a brilliant metallic bead, which on cooling becomes covered with a coating of black oxide.
Vitreous copper	Cu_2S .	—	Evolves SO_2 , and when pulverised and gently heated for some time, is converted into Cu O .	Fuses to a bead, which spurts considerably, gives off a white smoke. When pulverised and roasted, converts into Cu .
Copper pyrites	Cu_2FeS_4	Decrepitates, sometimes gives a sublimate of sulphur and becomes bronze colored on the surface.	Evolves SO_2 , and is finally converted into a dark red mixture of Fe_2O_3 and Cu O .	Fuses with a white sublimate on charcoal.

Behaviour				(8) Special reactions.
(1) Steps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
and the flame e.	In the oxidising flame dissolves and then gives the copper - reactions.	As in borax.	—	—
-	The roasted mineral gives the copper-reaction, and sometimes also a slight iron-reaction.	As in borax.	In the reducing flame is decomposed, forming Na S and metallic copper. If the former be cut out and laid upon silver, it gives the sulphur-reaction.	—
-	As the preceding; but when the copper has been removed by reducing on charcoal, the bead shows a strong iron color.	As the preceding; but the color in the oxidising flame is green, owing to the presence of iron.	Yields a bead of metallic copper, and some magnetic oxide of iron, which remains on the charcoal. The fused alkali gives a sulphur-reaction on silver.	—

COPPER. (Contin)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Fahlerz - -	$4(\text{Cu}, \text{Ag}_2\text{Fe}, \text{Zn}), \text{S} + (\text{Sb As})_2 \text{S}_3.$	Sometimes decrepitates, fuses, and when very strongly heated, gives a red sublimate of Sb_2S_3 with Sb_2O_3 , also sometimes a black sublimate of HgS and occasionally As_2S_3 .	Fuses and gives off thick fumes of Sb_2O_3 and SO_2 , also generally As_2O_3 , leaving a black infusible residue. If Hg be present, it is sublimed and condenses in the tube in small drops.	Fuses bead, fumes, and in the char with and some ZnO , cannot volatilize. Emits a smell of arsenic.
Tennantite -	$4(\text{Cu Fe}) \text{S} + \text{As}_2\text{S}_3.$	Decrepitates occasionally and gives a red sublimate of As_2S_3 .	Evolves SO_2 and As_2O_3 , which condense and form a white sublimate.	Fuses magnet giving arsenical sulphur fumes.

ages 194 and 195.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The residue obtained on charcoal thoroughly roasted gives a copper reaction, and when the latter has been removed by reduction upon charcoal, an iron-reaction.	As the preceding.	With this flux and a little borax yields a bead of metallic copper on silver; the alkaline mass gives a sulphur-reaction.	If the copper bead obtained by fusing upon carbonate of soda be cupelled with assay lead, a silver bead will be obtained. Or if dissolved in nitric acid and a drop or two of HCl added, a white precipitate of AgCl will be formed, which may be collected and reduced with carbonate of soda upon charcoal.
—	As the preceding.	As the preceding.	Yields a copper bead and metallic iron in the form of a dark grey powder. The fused alkali gives the sulphur-reaction.	—

COPPER. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Bournonite -	$3 (\text{Pb Cu}) \text{S} + \text{Sb}_2 \text{S}_3$	Decrepitates, giving off sulphur, and when strongly heated, $\text{Sb}_2 \text{S}_3$ and $\text{Sb}_2 \text{O}_3$.	Evolves thick white fumes of $\text{Sb}_2 \text{O}_3$ and Pb Sb O_3 . Also SO_2 .	Fuses and in the charcoal with and Pb ing a colored
Red oxide of copper	$\text{Cu}_2 \text{O}$	—	Is converted into the black oxide CuO .	In the charcoal reduces to metallic copper
Atacamite -	$3 \text{Cu H}_2 \text{O}_2 + \text{Cu Cl}_2 \text{H}_2 \text{O}$	Gives off much water, having an acid reaction on test paper, and forms a light grey sublimate of CuCl .	—	Fuses, the flask forms a grey sublimate charcoal is reduced to metallic copper, less small quantities of

as 196 and 197.)

Behaviour				(8) Special reactions.
(1) ceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
.	If the bead obtained on charcoal be fused on that support in the reducing flame with borax, a slight iron-reaction is obtained, and after a time a copper - reaction.	As with borax.	Yields a bead of metallic copper and lead, and incrusts the charcoal with Sb_2O_3 and PbO . The alkaline mass laid on silver and moistened gives the sulphur-reaction.	—
nd co- flame green, riously ened l, blue.	Gives the copper-reactions.	As with borax.	Is reduced to a bead of metallic copper.	—
nd co- outer tensely l green the nt.	Gives the copper-reactions.	As with borax.	Is reduced, yielding a bead of metallic copper.	—

COPPER. (Contir

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on ch
Diopside - -	$\text{Cu SiO}_3 + 3 \text{ Aq.}$	Gives off water and turns black.	—	In the ing fls comes In the ing fla
Malachite - -	$\text{Cu CO}_3 + \text{Cu H}_2\text{O}_2.$	Gives of water and turns black.	—	Fuse: bead a a stor: is red: metall P
Blue vitriol -	$\text{Cu SO}_4 + 5 \text{ Aq.}$	Intumesces, gives off water and becomes white.	Strongly heated is decomposed, giving off SO_2 and being converted into Cu O.	As in tl bulb. fuses, the out green, redne metalli per an

ges 198 and 199.)

Behaviour				(8) Special reactions.
4) repts.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
V. s the flame nely sen.	Gives the copper-reactions.	As with borax. The silica remains undissolved.	With a small quantity of carbonate of soda fuses to a bead, which on cooling is opaque and has a red fracture. With more alkali forms a slag, containing little beads of reduced copper.	—
and co- e outer rilliant- reen.	Gives the copper-reaction.	As in borax.	Yields metallic copper.	Dissolves in H Cl with much effervescence.
and co- e outer blue.	The roasted mineral gives the copper-reaction.	As in borax.	Yields metallic copper. The alkaline mass laid on silver gives the S-reaction.	Gives the sulphuric acid reaction (see p. 85).

COPPER. (Con

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	o
Libethenite -	$\text{Cu}_3 2 \text{PO}_4 + \text{Cu H}_2\text{O}_2.$	Gives off water and turns black.	—	G he bl fu ha of
Olivinite -	$\text{Cu}_3 2 (\text{As,P}) \text{O}_4 + \text{Cu}_2 \text{H}_2\text{O}_2.$	Gives off water.	—	F d an lu ni al lu te ha

Besides the above-mentioned minerals, the following are of importance:—Indigo copper (CuS), which behaves like vitreous copper, except that in the glass-bulb it gi

ages 200 and 201.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
as, but does color the e distinct- On cool- is black crystal- line.	Gives the cop- per-reaction.	As in borax.	With much of the alkali is decomposed, yielding me- tallic copper. With small portions suc- cessively added first fuses and then intumes- ces, fuses with a strong flame, and is then absorbed into the charcoal, leaving metal- lic copper.	Gives the phosphoric acid reaction (see p. 94).
as and co- the outer e green. cooling a crystal- surface.	Gives a cop- per-reaction.	As in borax.	Is reduced, yielding metal- lic copper.	Gives the ar- senic reac- tions (p. 92).

off a considerable quantity of sulphur. — Buntkupfererz
or horse flesh ore ($\text{Cu}_3 \text{Fe}_2 \text{S}_6$), which resembles copper py-
rites in its behaviour before the blowpipe, but may be easily

distinguished from this latter by its peculiar bronze color. — Chalcotrichite, which, being a dimorphous form of ruby copper, behaves similarly to that mineral. — Chrysocolla ($\text{Cu Si O}_3 + 3 \text{ Aq}$), which behaves like Diopside. — Azurite ($2 \text{ Cu CO}_3 + \text{Cu H}_2 \text{ O}_2$), the reactions of which are the same as those of Malachite. — Phosphorocalcite ($\text{Cu}_3 2 \text{ PO}_4 + 2 \text{ Cu H}_2 \text{ O}_2$), and some other phosphates, which behave in the same manner as Libethenite. — And finally Euchroite ($\text{Cu}_3 2 \text{ AsO}_4 + \text{Cu}_2 \text{ H}_2 \text{ O}_2 + 6 \text{ Aq}$), copper-froth ($\text{Cu}_3 2 \text{ AsO}_4 + 2 \text{ Cu H}_2 \text{ O}_2 + 7 \text{ Aq}$), copper-mica ($\text{Cu}_3 2 \text{ AsO}_4 + 5 \text{ Cu H}_2 \text{ O}_2 + 7 \text{ Aq}$), and Liroconite ($3 \text{ Cu}_3 2 (\text{As,P}) \text{ O}_4 + (\text{Cu}_3 \text{ Al}_2) \text{ H}_2 \text{ O}_2 + 27 \text{ Aq}$), which generally resemble Olivenite in their reactions, but differ therefrom in the following particulars: — Euchroite in the glass-bulb assumes a yellowish-green color and becomes friable. — Copper-froth and copper-mica fuse to a crystalline bead before the blowpipe, and Liroconite, when heated in the glass-bulb, gives off water, but does not decrepitate.

T I T A N I U M.

(Behaviour in borax and microcosmic salt see p. 69, with carbonate of soda p. 75, with nitrate of cobalt on charcoal p. 91.)

The only titanium minerals of sufficient importance to demand notice in this place are Rutile, Anatase, Brookite and Sphene. Of these the first three are trimorphous forms of titanic acid, generally containing a small quantity (about 1 %) of iron or manganese, and are easily recognised by their exhibiting all the blowpipe characters of titanic acid, slightly modified by the oxides just mentioned. The most characteristic reaction of titanic acid is the color im-

parted by it to microcosmic salt in the reducing flame, which only resembles that produced in the same flux by niobic acid. From this latter rare acid, titanitic acid is sufficiently distinguished by its behaviour in borax, and especially in the reducing flame.

¹ Rutile, Anatase and Brookite (TiO) are anhydrous; they are infusible before the blowpipe, and impart no color to the outer flame. With carbonate of soda and nitre they frequently give a slight manganese reaction, and with carbonate of soda alone fuse to a clear bead, which becomes opaque on cooling. They are distinguishable from one another solely by their physical characters.

Sphene [$(\text{Ca} + \text{Ti}_2) \text{O}$, Si O_4], when heated in the glass-bulb, usually gives off a trace of water, and the brown varieties assume a yellow color. In the forceps it fuses on the edges with intumescence to a dark glass. In borax it dissolves readily to a clear yellow glass, and in microcosmic salt the lime and titanitic acid dissolve with difficulty, leaving the silica undissolved. If the microcosmic bead containing titanitic acid be treated with tin upon charcoal, it assumes the characteristic violet color of titanitic acid.

Titanitic acid occurs in considerable proportion in Ilmenite and Iserine, for which minerals see Iron, page 144.

T I N.

(Behaviour on charcoal p. 28, in borax and microcosmic salt p. 64, with carbonate of soda p. 75, with nitrate of cobalt p. 91.)

When tin minerals are fused with carbonate of soda, or better with cyanide of potassium in a strongly reducing

flame upon charcoal, they yield small globules of metallic tin malleable when cold, and the charcoal around becomes covered with a white coating of the oxide. If this incrustation be treated with cobalt-solution in the usual manner and strongly heated, it assumes a bluish-green color very characteristic of the oxide of tin. By this reaction tin-stone and tin-pyrites, the only important minerals of this metal, may be easily recognised. — Their other reactions are as follows : —

Tin-pyrites or bell metal ore ($2(\text{Cu, Fe, Zn})\text{S} + \text{SnS}_2$), heated in the open tube, gives off SO_2 and SnO_2 , which is deposited just above the assay. In the reducing flame on charcoal it fuses to a bead, but in the oxidising flame is converted into oxide of tin, a part of which incrusts the charcoal and may be tested with nitrate of cobalt. If, having been roasted under the oxidising flame, it be treated with borax in the reducing flame, an iron-reaction will be obtained ; but if with the oxidising flame, the borax will be rendered blue from copper. Tin-pyrites frequently contains a small quantity of zinc, but as the tin interferes with the reactions of this metal on charcoal, its presence can only be ascertained by a wet analysis.

Tin-stone (SnO_2) is anhydrous and infusible. In borax and microcosmic salt it usually gives a slight iron-reaction, and with carbonate of soda and nitre indications of manganese are very frequently obtained.

M O L Y B D E N U M.

(Behaviour on charcoal p. 28, in the forceps and on platinum wire p. 36, in borax and microcosmic salt p. 73, with carbonate of soda p. 75.)

The only mineral of molybdenum (besides molybdate of lead described at page 190) of sufficient importance to demand notice in this place is the sulphide of molybdenum or molybdenite (MoS_2). This mineral, which in its general appearance much resembles graphite, is very easily recognised by the following blowpipe characters. Heated in the glass-bulb it sometimes gives off a trace of sulphur and becomes bronze-colored on the surface, but undergoes no further change. In the open tube it gives off sulphurous and molybdic acid, of which the former passes off and may be recognised by its peculiar odor, while the latter condenses in minute white crystals in the upper part of the tube. On charcoal it is infusible, but in the oxidising flame is slowly roasted, and incrusts the charcoal with a characteristic deposit of molybdic acid, which, if taken up on a fluid borax or microcosmic bead, exhibits the reactions described at page 73. In the forceps it colors the flame green, but is perfectly infusible in the most intense part of the flame. Fused with carbonate of soda it is decomposed, and sulphide of sodium and molybdic acid result, the former of which laid upon silver and moistened gives the sulphur-reaction. The molybdic acid is partially volatilised and incrusts the charcoal around the fused mass.

TUNGSTEN.

(Behaviour in borax and microcosmic salt p. 72, with carbonate of soda p. 75.)

Of the three principal tungsten-minerals, viz.:—Wolfram, Scheelite and Scheelite (CaO , WO_3), the first two have been already noticed under Iron and Lead (pages 144 and 180). The remaining mineral, Scheelite, is easily recognised by the following reactions. On charcoal or in the forceps it fuses on the edges to a translucent glass, but does not color the blowpipe flame. In borax it dissolves readily to a clear glass, which, when it contains a considerable proportion of the mineral, becomes crystalline on cooling. In microcosmic salt it also dissolves to a clear glass, which, when treated in the reducing flame, becomes blue on cooling, thus indicating the presence of tungstic acid. With carbonate of soda it forms a tumid, white, almost infusible slag. As non-essential constituents it frequently contains iron, manganese and fluorine, of which the first may be detected by the color it imparts to the borax bead, the second by its characteristic behaviour when fused with nitre and carbonate of soda, and the third by its action on a glass-tube when fused with microcosmic salt. See page 86.

A N T I M O N Y.

(Behaviour in the open tube p. 23, on charcoal p. 23, in borax and microcosmic salt p. 71, with carbonate of soda p. 75, with nitrate of cobalt p. 91.)

When antimony minerals are heated with access of air, either in the open tube or on charcoal, they give off dense white fumes of antimonious and antimonie acid, which are deposited on the support at a short distance beyond the assay. This behaviour is very characteristic of antimony, and is an unmistakable indication of its presence. The peculiar phenomenon exhibited by a bead of metallic antimony when fused upon charcoal, and which is described at page 26, is also characteristic, and may be produced by reducing the antimony mineral (if a sulphide or oxide) with carbonate of soda upon charcoal, and operating upon the metallic bead so obtained.

Mineral.	Formula.	Behaviour	
		(1) in glass-bulb.	(2) in open tube.
Native anti- mony	Sb.	Fuses, and when strongly heated, volatiles, being re-deposited in the tube as a dark grey sublimate.	Fuses and gives off dense white fumes, which are partly re-deposited on the tube. Sometimes also gives off arsenical fumes in small quantity.
Grey antimony	Sb_2S_3 .	Fuses readily and occasionally gives off a small quantity of sulphur. Strongly heated forms a brown sublimate of SbS_3 and SbO_3 .	Fuses and gives off SO_2 , which passes off up the tube, and dense white fumes of SbO_3 , and SbO_5 , which are partly deposited in the tube.

Behaviour				(8) Special reactions.
(4) ceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
.	The oxide formed upon charcoal gives the antimony reactions.	As in borax.	—	The incrustation on the charcoal, if treated with nitrate of cobalt, assumes the characteristic green color.
.	As the preceding.	As in borax.	Fuses and is reduced, yielding metallic antimony, which behaves as the preceding mineral upon charcoal. The alkaline mass gives the sulphur reaction.	As the preceding.

ANTIMONY. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Antimony blende	$\text{Sb}_2\text{O}_3 + 2\text{SbS}_3$	Fuses easily, gives off first Sb_2O_3 and afterwards an orange-colored sublimate. Strongly heated is decomposed and gives a black sublimate, which becomes brown on cooling.	As the preceding.	As the cedin
White antimony	Sb_2O_3	Is sublimed and recondensed in the neck of the tube.	As in the glass-bulb.	Fuses with evolution of dense fumes, which incrust surface of charcoal. The red flame is reduced, indicating metallic antimony. Colors of flame.

ages 210 and 211.)

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	As native antimony.	As in borax.	As the preceding.	As native antimony.
is and is fused, cooling the flame blue.	Gives the antimony reaction.	As in borax.	In the reducing flame is reduced, yielding metallic antimony.	As native antimony.

The above are the principal minerals in which antimony is the only metal present. Arsenical antimony (SbAs) is comparatively of rare occurrence, and resembles native antimony in its reactions, except that, when heated either in the glass-bulb, the open tube, or on charcoal, it gives off considerable arsenical fumes, easily recognised by their odor.

A very large and important class of antimony minerals, viz. those in which antimony is combined with lead and sulphur, as Jamesonite, Zinkenite, Heteromorphite, etc., have been already described under Lead. Fahlerz and Bouruonite under Copper, and Ulmannite under Nickel. For antimonial silver, Stephanite, Pyrargyrite, Miargyrite and Polybasite, see Silver.

A R S E N I C.

(Behaviour in glass-bulb p. 21, in open tube p. 23, on charcoal p. 25, in forceps p. 33, with carbonate of soda p. 75. Mode of detecting small quantities in combination with metals p. 92.)

Arsenic is readily recognised in its unoxidised compounds by the peculiar garlic-like odor which it gives when heated in an open tube, on charcoal or elsewhere. In the form of arsenious or arsenic acid the same indication of its presence is obtained by reducing the acid upon charcoal with the addition of carbonate of soda or oxalate of potash, if in combination as an arseniate or arsenite. It is scarcely necessary to remark that any blowpipe experiments upon arsenical compounds should be carried on in a well-ventilated room, since the arsenical fumes produced therein are highly prejudicial to health if not speedily removed.

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on char
Native arsenic	As.	Sublimes without fusion and recondenses as a dark grey metallic sublimate, sometimes leaving a small residue.	If gently heated in a good current of air passes off as AsO_3 , which is partly condensed as a white sublimate in the upper part of the tube.	Passes as AsO_3 , thinly in the char beyond assay.
Realgar - -	As_2S_2 .	Fuses, enters into ebullition and is sublimed as a transparent red sublimate.	Gently heated passes off as SO_2 and AsO_3 , the latter of which is redeposited in the upper part of the tube.	Fuses passes as arsenious sulphuric acid.
Orpiment - -	As_2S_3 .	As the preceding, except that the sublimate is of a dark yellow color when cold.	As the preceding.	As the preceding.
White arsenic	As_2O_3 .	Sublimes without fusion and recondenses in white crystals.	—	Sublimes is partly condensed on charcoal, giving a crust.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
ors the is blue.	—	—	—	—
and co- he flame blue.	—	—	As on char- coal, except that the S combines with the alkali forming NaS, which on silver gives the sul- phur-reaction.	—
he pre- ceding.	—	—	As the pre- ceding.	—
ors the is blue.	—	—	—	Heated with charcoal in a glass-tube sealed at one end, is reduced and metallic arsenic sub- limes.

The earthy residue left by metallic arsenic after sublimation, if treated with borax or microcosmic salt, generally gives the reaction of iron, and sometimes that of nickel and cobalt. If fused upon charcoal with a little borax and assay lead, and the lead be afterwards cupelled in the manner described under Silver (page 223), a minute bead of silver is occasionally obtained.

Besides the minerals mentioned in the above table the following are important, viz.:—Pharmacolite described under Lime; Mispickel, Leucopyrite, Scorodite and cube ore under Iron (page 144); copper nickel, Smaltine, glance cobalt, nickel glance, Ulmannite, cobalt bloom, and nickel ochre, under Nickel and Cobalt (page 163); Mimetene and geocronite under Lead (page 180); Fahlerz, Tennantite, Olivenite and other arseniates of copper under Copper (page 193); and Proustite and Polybasite, for which see Silver (page 223).

M E R C U R Y.

(Behaviour in the glass-bulb see p. 21, with carbonate of soda p. 75.)

If any mineral containing mercury be mixed with carbonate of soda and heated in a glass tube sealed at one end, metallic mercury will be evolved, and condensing in the upper part of the tube run together into small drops easily distinguishable by their metallic lustre. The following are the principal minerals of mercury.

Native mercury frequently contains a small quantity of silver, which, when the mercury is driven off in the glass-bulb, remains in the residue and may be fused with a little carbonate of soda on charcoal to remove any earthy impurities.

Besides the minerals below mentioned are the following of more rare occurrence:—Horn quicksilver (Hg_2Cl) and selenide of mercury [$\text{Hg}(\text{SSe})$], easily recognised by their chlorine- and selenium-reactions respectively. Fahl-erz and selenide of lead also occasionally contain mercury (see Copper and Lead).

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charc
Native mercury	Hg.	Volatilises with little or no residue, and recondenses in neck of bulb.	—	Is volatil
Cinnabar - -	Hg S.	Volatilises, sometimes leaving a light earthy residue, and recondenses as a black sulphide.	If gently heated is decomposed into metallic mercury, which volatilises and recondenses in the upper part of the tube, and SO ₂ , which passes off and is easily recognised by its odor and bleaching properties.	Is volatil generally leaving a s earthy resi
Native amalgam	Ag Hg ₂ .	As native mercury, but leaves a residue of pure silver.	—	The mer volatil leaving silver, w fuses to bead, and the oxid flame, inc the char with its c racteris oxide.

Behaviour				(8) Special reactions.
(4) forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	—	—	—	—
—	—	—	With carbonate of soda and cyanide of potassium is decomposed, and metallic mercury volatilised.	When in the preceding experiment the mercury has been entirely dissipated, the alkaline residue laid on silver gives a sulphur-reaction.
—	—	—	—	—

PLATINUM, PALLADIUM, RHODIUM, IRIDIUM,
AND OSMIUM.

These metals, which only occur native or in the form of alloys, are principally characterised by their negative properties being infusible before the blowpipe,*) and, with the exception of osmium and palladium, not acted upon by any of the ordinary blowpipe fluxes. Osmium, when fused with nitre upon charcoal, evolves fumes of osmic acid having a peculiar unpleasant odor; and palladium, when fused in a large glass-bulb with bisulphate of potash, is dissolved forming a yellow salt. The principal mineral species in which the above metals occur are:

Native platinum, which generally contains more or less iron, iridium, rhodium, palladium, osmium and copper. If some filings of this mineral be fused with borax or microcosmic salt, the flux exhibits a slight copper- and iron-reaction, but the other metals remain unacted upon. In order to separate these, a chemical analysis is necessary, for which see *Rose's "Analytical Chemistry."*

Native palladium, which fuses with bisulphate of potash as above mentioned. It also fuses with sulphur in the reducing flame on charcoal, and if afterwards treated in the

*) An extremely thin platinum wire or fine strip of platinum foil may be fused before the point of the blowpipe flame, but as anything larger than this, as e.g. the grains, in which platinum occurs native, remains unaltered in form, the metal may be practically termed infusible.

oxidising flame, the sulphur is burnt off, leaving metallic palladium.

Iridium osmium and osmium iridium, two distinct combinations of these two metals. The former, having the formula IrOs , is infusible alone, and when fused with nitre, gives off fumes of osmic acid. The latter, having the composition IrOs_3 or IrOs_4 , if heated in the flame of a spirit lamp, gives off osmium, which renders the flame brilliantly illuminating. With saltpetre it gives off a greater quantity of acid fumes than the other species.

S I L V E R.

(Behaviour on charcoal p. 28, in borax and microcosmic salt p. 67, with carbonate of soda p. 75.)

According to their composition we may divide the silver minerals into two classes: first, those containing no other fixed metal but silver, which may consequently be extracted by a simple fusion with carbonate of soda upon charcoal, the antimony, arsenic or sulphur present being volatilised, the two former under the reducing, the latter under the oxidising flame: — second, those which, as argentiferous fahlerz, contain, in addition to silver, copper, lead, etc., which are either fixed metals or can with difficulty be volatilised under the blowpipe flame. In such cases, in order to ascertain the presence of silver, the following process is to be resorted to:

A nearly cylindrical hole about $\frac{3}{16}$ of an inch deep and of the same diameter having been bored in a good piece of charcoal, about 2 grains weight of the mineral, previously pulverised, and mixed with its own bulk of

pounded borax-glass, is wrapped up in a small piece of thin assay lead, introduced into the cavity and fused under the reducing flame, at first gently, and afterwards more strongly. This should be kept up, until the whole mass has resolved itself into a metallic button and a clear glassy borax bead not adhering to the charcoal. If the metallic button on cooling present a dull grey surface, indicating the presence of antimony, it must then be treated in the oxidising flame, until on cooling it presents a bright somewhat prismatic surface. It is then detached from the borax and carefully cupelled on some bone-ash pressed into a shallow cavity in a piece of charcoal, the surface being smoothed and made slightly concave with the end of an agate pestle. The cupellation is thus effected:—The bone-ash cupel is first strongly heated in order to drive off any moisture contained in it. The metallic button, carefully freed by hammering from any adhering fragments of borax, is then placed upon it, and kept fused beyond the point of a gentle oxidising flame, until the greater portion of the lead is oxidised, and forms a mass of fused litharge around the metallic bead. This latter, when cold, is removed, and being cleaned from the litharge by a gentle blow with a hammer, is placed upon a second cupel prepared and dried in a similar manner to the first, and having a very smooth surface of fine bone-ash. The cupellation is then resumed as before, except that the flame is directed rather on the cupel immediately in front of the bead, than on the bead itself, so that the litharge is absorbed by the cupel as rapidly as it is formed. The flame is to be continued until brilliant prismatic colors play over the surface of the

bead, indicating the oxidation of the last traces of lead. The flame is then stayed and the bead allowed to cool. If consisting of pure silver, or silver and gold, when just cooled below redness, it suddenly glows for a second, and then on cooling presents the brilliant white surface of fine silver. If one cupellation be not sufficient to remove all the copper, a fact which is indicated by the color of the litharge absorbed by the second cupel being not of a pale yellow when cold, but inclining to black, the bead should be remelted with a small quantity of assay lead and the cupellation repeated. — By this process, when carefully conducted, the per-centage of silver in a mineral may be estimated very accurately; but if such be the object of the blowpipist, it is desirable to obtain a few pieces of apparatus specially constructed for blowpipe assaying, for a detailed description of which, as well as of the mode of conducting the process, the student is referred to Professor *Plattner's* work on the blowpipe. The principal silver minerals are the following:

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Native silver -	Ag.	—	—	Fuses at a strong disintegration forms a crustate dark oxide of charcoal any antimony be present affords a strong reaction
Antimonial silver	Ag ₂ Sb.	—	Gives off dense white fumes, which are partly deposited in the tube.	Fuses, strongly incrusting and white antimony nearly led a crustone; a pure bead re
Silver glance -	Ag ₂ S.	—	Gives off sulphurous acid.	Gives off and is reduced to metallic silver. pure, a quantity of slag also main

Behaviour				(8) Special reactions.
(4) in forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	Gives the silver - reactions (p. 224).	As in borax.	—	—
—	The incrustation formed on charcoal gives an antimony-reaction.	As in borax.	As alone on charcoal.	—
—	The residual slag (if any) obtained upon charcoal gives an iron-reaction.	As in borax.	As alone on charcoal. The alkaline mass gives a sulphur-reaction on polished silver.	—

SILVER. (Conti

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	on c
Stephanite -	$\text{Ag}_5 2 \text{Sb S}_4$	Decrepitates, fuses and gives a slight sublimate of sulphide of antimony.	Fuses and gives off SO_2 and dense white antimonial fumes.	Fus incre char anti acid; Ag v antin the conti red tioni and bead silver surro a su
Pyrargyrite -	$\text{Ag}_3 2 \text{Sb S}_3$	Sometimes decrepitates, fuses readily, and, when strongly heated, gives a dark red sublimate of Sb S_3 .	As the preceding.	Fus much and char ant fume the AgS for s in th ing bead silver t

pages 226 and 227.)

Behaviour				(8) Special reactions.
(4) 1 forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	The residual slag obtained on the charcoal gives an iron- and copper-reaction.	As in borax.	The silver is reduced and the antimony passes off in dense fumes. The fused alkali gives the sulphur-reaction on silver.	—
—	—	—	As the preceding.	—

SILVER. (Continued)

Mineral.	Formula.	Behaviour		
		(1) in glass-bulb.	(2) in open tube.	(3) on charcoal
Proustite - -	$\text{Ag}_3 2 \text{As S}_3$	Fuses and at a low red heat affords a small sublimate of As S_3 .	Gradually heated it gives off As O_3 and S O_2 . Sometimes also antimony-fumes.	As the ceding, cept the large quantities of As O_3 , but little are given
Horn silver -	Ag Cl .	Fuses, but undergoes no further change.	—	Fuses in the oxidising flame the red flame is almost reduced yielding metallic silver

Other argentiferous minerals are:—Miargyrite ($\text{Ag}_2 \text{Sb}_2 \text{S}_4$), which behaves similarly to Stephanite.—Polybasite [$(\text{Ag}_2 \text{Cu})_{10} (\text{Sb} + \text{As})_2 \text{S}_{13}$], which in the glass-bulb fuses with extreme ease, but gives no sublimate. In the open tube it gives off fumes of antimony and arsenic, the latter forming a crystalline sublimate. On charcoal it behaves as Pyrargyrite, except that it gives off much arsenic and yields a bead of metallic silver containing a considerable quantity of copper, as may be ascertained by fusing under the oxidising flame with microcosmic salt upon charcoal. The mineral sometimes also forms a thin zinc incrustation on the charcoal just beyond the assay, and easily recognisable by its yellow color while warm.—Bromide of silver

pages 228 and 229.)

Behaviour				(8) Special reactions.
(4) in forceps.	(5) in borax.	(6) in mic. salt.	(7) with carb. soda.	
—	—	—	As stephanite, except that much arsenic is given off and but little antimony.	—
—	—	—	Is rapidly reduced to metallic silver.	If cut up into small pieces mixed with oxide of copper and then heated before the oxidising flame upon charcoal, it colors the flame blue.

(Ag Br), Iodide of silver (Ag I), and bromo-chloride of silver ($2 \text{ Ag Br} + 3 \text{ Ag Cl}$), which in general reactions resemble horn silver, but may be distinguished by the different colors they impart to the blowpipe flame, when treated with oxide of copper upon charcoal, and by their behaviour when fused with bisulphate of potash in a glass-tube sealed at one end.

In addition to the above, most lead minerals contain a small quantity of silver, especially tinder ore, for which see Lead (page 180); also Bournonite and Weissgültigerz (see Copper); native amalgam, described under Mercury (page 219); and graphic tellurium and gold, for both of which see that metal.

G O L D.

Besides native gold, which is easily recognised by its color, malleability and other physical characters, the only important minerals containing gold in any considerable quantity are graphic tellurium and foliated tellurium. Gold occurs, however, in small quantities in several metallic sulphides, but in such minute proportion as only to be discoverable on fusing 5 or 6 thousand grains of the mineral with lead, and carefully cupelling and parting the result. The detection of such minute quantities of gold does not therefore fall within the province of blowpipe assaying, and the only minerals we have here to consider are such as contain sufficient of the metal as to be detectable by an ordinary blowpipe cupellation.

In order to ascertain the presence of gold in any mineral in which it is present with other non-volatile metals, the mineral should be pulverised and fused with borax and lead (and the metallic bead resulting from the fusion cupelled in the manner described in the paragraph on silver). If the bead obtained by cupellation contain sufficient silver to give it the color and appearance of that metal, in order to separate the gold in a pure state, it should be beaten out on a clean metallic surface, and then placed in a porcelain capsule with a few drops of nitric acid, and warmed gently in order to aid the solution of the silver. When all action has ceased, the silver solution is to be poured off, and the gold prill washed with distilled water, and then carefully transferred to a piece of charcoal, on which it is heated by the blowpipe flame to a bright

red heat. This causes it to cohere, and it then assumes the well-known appearance of fine gold. If the gold bead after cupellation have a pale gold color, indicating the presence of silver in small quantity only, a bead of silver from 2 to 4 times its own weight should be added, and the whole fused together, beaten out and then treated with nitric acid, in order to separate the gold. The former part of the above process, viz. the fusion, is only requisite in extracting gold from metallic ores or from mineral masses in which it is disseminated, and is unnecessary in the examination of the following minerals; but as gold is generally combined with more or less silver and smaller quantities of copper, iron, etc., in order to obtain the pure gold, it is always desirable to cupel and part it.

Native gold is best recognised by its physical characters, as its weight, color, sectility, malleability, etc. It is fusible at a bright red heat, and, when fused with micro-cosmic salt on charcoal under a good oxidising flame, the latter becomes opalescent from the presence of silver. By cupellation to remove slight traces of iron and copper, and subsequent parting with the addition of silver, nearly all the foreign metals may be separated and a prill of fine gold obtained.

Graphic tellurium.—In the open glass-tube gives off tellurous acid, which forms a white sublimate, and, when reheated, runs together into small transparent drops. It is easily recognised by its peculiarly disagreeable smell. On charcoal graphic tellurium fuses to a bead forming an incrustation of telluric acid on the charcoal (see page 25). When the tellurium is dissipated, a pale yellow metallic

bead remains, which, when parted, yields a prill of fine gold.

Foliated tellurium in the open tube gives off white fumes, which are partly deposited in the tube above the assay, and consist of tellurate and antimoniate of lead, and in the upper part of the tube of antimonious acid and tellurous acid. On charcoal it fuses and forms a yellow incrustation of oxide of lead around the assay and a white incrustation of antimonious and tellurous acid and sulphate of lead. When these and the lead have been completely driven off, a gold bead remains.

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